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CONTENTS

Upper Jurassic pelecypods from Mexico ..... *Ralph W. Imlay* 393
New larger Foraminifera from the Claiborne of Mississippi ..... *Donald W. Gravell and Marcus A. Hanna* 412
Conodonts from the Devonian and associated clays of Minnesota .. *Clinton R. Stauffer* 417
The apical end of *Actinoceras* ..... *Rousseau H. Flower* 436
Some Devonian Actinoceroidea ..... *Rousseau H. Flower* 442
Blastocerina, new name for *Blastoceras* Flower and Caster ..... *Rousseau H. Flower* 447
Avian remains from the Pleistocene of central Java ..... *Alexander Wetmore* 447
Holotype of *Plesiosaurus longirostris Blake* and classification of the plesiosaurs ..... *Theodore E. White* 451
Ceratopsidae from Alberta ..... *C. M. Sternberg* 468
Thescelosaurus edmontonensis, n.sp., and classification of the Hypsilophodontidae ..... *C. M. Sternberg* 481
Cranial foramina of North American beavers ..... *Everett Claire Olson* 495
Sphaerospongia in the Tully formation ..... *John W. Wells* 502
Two new Cypraeas from Costa Rica ..... *William M. Ingram* 505
Supplementary notes on the occurrence of Tertiary Noetinae .... *F. Stearns MacNeil* 507
Pliocene mollusks from a well at Sanford, Florida ..... *Sidney A. Stubbs* 510
Corrections to the basal Bonneterre fauna ..... *Christina Lochman* 515
Aisataspis bakeri, a new Lower Ordovician trilobite ..... *F. E. Turner* 516
Cantharus bentsonae, new name for *C. cowlitzensis* Turner ..... *F. E. Turner* 518
A Pleistocene occurrence of *Libinia dubia*, a brachyuran ..... *William H. Easton* 519

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VOLUME 14 SEPTEMBER, 1940 NUMBER 5

UPPER JURASSIC PELECYPODS FROM MEXICO

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ABSTRACT—The Upper Jurassic near-shore deposits of the Mexican geosyncline contain an abundance of pelecypods and few ammonites in contrast to the offshore deposits, where the proportions are reversed. Most of the pelecypods are identical with species in the Malone formation of western Texas. The presence of some ammonites in the near-shore deposits furnishes a means of correlation between the various facies and confirms the Jurassic age of the pelecypods in spite of their supposed Cretaceous affinities.

ACKNOWLEDGMENTS

MOST of the fossils described in this report were collected during the summers of 1931 to 1937 in the course of geological studies in northern Mexico financed by the Penrose Bequest of the Geological Society of America. A few fossils from Nuevo León were obtained by E. R. Silliman in 1925 while in the employ of the East Coast Oil Company and were subsequently given to the University of Michigan. Dr. John B. Reeside, Jr., personally examined some of the fossils and accorded the writer the privilege of inspecting Jurassic type specimens in the National Museum.

PALEOGEOGRAPHIC RELATIONSHIPS

Burckhardt (1930, p. 103) visualized the Mexican sea of Upper Jurassic time as an arm of considerable size enclosed on all sides by land masses except toward the southeast in the state of Vera Cruz. Later work has not greatly modified this picture (fig. 1). Müllerried (1936, p. 35–37) found the Jurassic well developed in northern Chiapas in facies similar to the Jurassic in Oaxaca and Puebla and, like the latter, showing the presence of a southern borderland. Connection of the Mexican sea with the Pacific waters through southern or northern Mexico has been suggested (Schuchert, 1935, p. 156; Kellum, Imlay, and Kane, 1936, pp. 981–983; Burckhardt, 1930, p. 104) but has not been proven. Recent work (Imlay, 1938b, p. 1888) suggests that a northern portal to the Pacific did not exist during the Upper Jurassic. However the main modifications of the paleogeographic picture, as conceived by Burckhardt, have been made for northeastern Mexico, where the approximate outlines of two peninsulas extending southward from the region of Texas have been determined. The western, or Coahuila Peninsula, terminated rather broadly on the south and divided the Mexican sea into a large western basin and a small eastern basin. The eastern peninsula apparently coincided roughly with the eastern margin of the present Sierra Madre Oriental and terminated toward the south in the States of Vera Cruz and Hidalgo. The distribution of clastic sediments indicates that the peninsula passed southward into an archipelago and that it was bordered by small islands, but as yet only the Miquihuana Island has been definitely demonstrated. From the region of Miquihuana to

U N I T E D S T A T E S
MEXICO
GOLFO DE MEXICO
BAJA CALIFORNIA
GOLFO DE CALIFORNIA
SONORA
CHIHUAHUA
COAHUILA
NUEVO LEON
TAMAULIPAS
DURANGO
SINALOA
ZACATECAS
SAN LUIS POTOSI
NAYARIT
JALISCO
MICHOACAN
GUERRERO
OAXACA
HIDALGO
MEXICO
PUEBLA
VERACRUZ
TABASCO
CHIAPAS
YUCATAN
CAMPECHE
QUINTANA ROO
BAHIA DE CAMPECHE
GOLFO DE TEHUANTEPEC
AMERICA CENTRAL
STATUTE MILES
KILOMETERS
LEGEND
X — OFF-SHORE FACIES WITH CEPHALOPODS DOMINANT.
● — NEAR-SHORE OR MIXED FACIES WITH BIVALVES DOMINANT
1. MALONE; 2. PLACER DE GUADALUPE; 3. SANTA DOMINGO; 4. CUCHILLO PARADO; 5. SIERRA RICA; 6. SAN PEDRO DEL GALLO; 7. PUERTO DE LAS SARDINAS; 8. VILLA JUAREZ; 9. SIERRA DE JIMULCO; 10. WESTERN PART SIERRA DE PARRAS; 11. MIDDLE PART SIERRA DE PARRAS; 12. SIERRA DE RAMIREZ; 13. SIERRA DEL CHIVO; 14. PICO DE TEYRA; 15. SIERRAS DE ZULOAGA AND SOMBRERETILLO; 16. SIERRAS NEAR MAZAPIL; 17. SIERRA DE LA VENTURA; 18. SAN MARCOS; 19. MENCHACA; 20. SIERRA AZUL; 21. SAN AMBROSIO WELL NO. 1 NEAR CAMARON; 22. SIERRAS BETWEEN MONTERREY AND SALTILLO; 23. CIENEGA DEL TORO; 24. NORTHEASTERN PART OF SIERRA DE SAN CARLOS; 25. LA ESCONDIDA; 26. LAS VIRGENES; 27. SIERRA WEST OF CIUDAD VICTORIA; 28. SAN LAZARO; 29. DOCTOR ARROYO; 30. MIER Y NORIEGA; 31. SIERRA DE CATORCE; 32. PEÑON BLANCO; 33. PINOS; 34. CHOCOY WELL NO. 2; 35. ALTAMIRA WELL NO. 11; 36. JALPAN; 37. TAMAZUNCHALE; 38. HUAYACOCOTLA; 39. HUALCHINAGO; 40. POZA RICA WELL NO. 6 NEAR COATZINTLA; 41. TEZIUTLAN; 42. ALMANZA; 43. CONSUELO; 44. TLAXIACO; 45. SANTA DOMINGO IXCATLAN; 46. AMOLTEPEC; 47. CHINAMECA; 48. RIO PLAYAS; 49. BISBEE; 50. REGION BETWEEN CABORCA AND PITIQUITO; 51. REGION NEAR HERMOSILLO.

FIG. 1.—Upper Jurassic paleogeography of Mexico.

Monterrey, land must have been continuous and in places fairly high (Böse and Cavins, 1927, pp. 81–82; Burckhardt, 1930, pp. 84–91, 101). Evidence for the northward continuation of this land to the region of Texas consists of the occurrence of (1) Upper Jurassic marls and limestones with *Exogyra* cf. *virgula* Defrance in the Sierra de Azul, Coahuila (Burckhardt, 1930, pp. 84, 143–144, fig. 39) and (2) of black, carbonaceous limestone with an ammonite, *Kossmatia*, and many bivalves in the San Ambrosio well no. 1, near Camarón, Nuevo León (Burckhardt and Müllerried, 1936, pp. 314, 317, 320). The presence of *Kossmatia* proves the Portlandian age of the beds. The bivalves and carbonaceous material show nearness to a land. The Jurassic was penetrated by the boring only about 460 feet but is overlain by Neocomian and younger Lower Cretaceous rocks which are more than three thousand feet in thickness. The occurrence of these sediments in the region of the Rio Grande embayment suggests that the latter may have existed as early as Upper Jurassic times. This view seems to harmonize with the recent work of Hazzard (1939, pp. 174–175) concerning an Upper Jurassic transgression across Louisiana, Texas, and Arkansas.

Attention may be drawn here to a reported occurrence of marine Jurassic in the Puerto de las Sardinas in the Sierra del Sobaco of western Coahuila (Burckhardt and Müllerried, 1936, pp. 313–314). The Jurassic assignment is based on *Phylloceras* sp. and *Sowerbyceras* sp. Only the latter would definitely indicate an Upper Jurassic age. The writer questions the age determination because the area has been studied in some detail by Kelly (1936, p. 1023, pl. 13), who found the Cuchillo formation of Trinity age resting on Permian shales. No Jurassic rocks were observed in the Sierra del Sobaco nor in the Sierra de Tlahualilo farther west. Many reasons have been given elsewhere for considering these areas as parts of a land mass during Upper Jurassic time (Kellum, Imlay and Kane, pp. 972, 973, 976, 985, 1005).

During the Upper Jurassic the waters occupying the Mexican geosyncline gradually transgressed on the bordering land masses and then withdrew a little at the close of the period as the land masses were elevated. The conditions of sedimentation varied somewhat in different parts of the Mexican geosyncline. However, for its northeastern and central parts, with which the writer is familiar, certain generalizations may be drawn. In these parts the sediments laid down during the Oxfordian stage consisted mainly of off-shore thick-bedded limestones containing marly intercalations at infrequent intervals, and of near-shore sandstones and conglomerates. Shales are singularly uncommon. The off-shore deposits have been called the Zuloaga limestone, and the near-shore deposits La Gloria formation. On the basis of their thick-bedded character and the occurrence of coral and gastropod beds, the off-shore deposits were considered by Burckhardt (1930, pp. 71, 102) to have been deposited in warm, shallow, much agitated waters. He interpreted the marly intercalations as indicating periodic sinking of the geosyncline. However they might as reasonably be interpreted as indicating minor climatic variations. The dominant yellowish color and the scarcity of shale in the near-shore deposits possibly indicate aridity on the surrounding land masses. Recent studies by Baker, Dane, and Reeside (1936, pp. 54, 55, 58) of the San Rafael group of the Southern Rocky Mountain Province testify to the aridity of the land north of the Mexican geosyncline during early Upper Jurassic time. It seems likely that the Todos Santos series of red beds and rock salt in the isthmian region of Vera Cruz, Tobasco, Chiapas, and northern Guatemala were formed in part about this time and in part earlier in the Jurassic (Burckhardt, 1930, pp. 96–97; Müllerried, 1936, pp. 35–37; Sapper, 1937, pp. 44, 45, 92, 101). Müllerried states that the Jurassic series of northern Chiapas consists of two parts. The lower part contains plant remains and corresponds to the continental deposits of the Lower and Middle Jurassic of Oaxaca and Puebla. The upper part consists of marine sediments of Upper Jurassic age.

Beginning with the late Oxfordian or early Kimmeridgian a marked change occurred in the characteristics of the Jurassic sediments deposited in the northern and central parts of the Mexican geosyncline. Large quantities of dark muds were brought

FIG. 1.—Upper Jurassic paleogeography of Mexico.

to the sea and widely distributed. The off-shore deposits of limestones, marls and shales, called La Caja formation, were deposited according to Burckhardt (1930, pp. 71, 72, 102) "in the tranquil waters of the deeper part of the neritic zone," as indicated by the abundance of ammonites and the rarity of benthonic forms. However the rarity of the latter might be due to an abunance of mud rather than to any great depth of water. The near-shore deposits of conglomerates, sandstones, shales, marls, gypsum, and carbonaceous deposits, called La Casita formation, vary considerably in thickness and lithology from place to place. The gypsiferous and carbonaceous beds indicate lagoonal conditions. The large amounts of conglomerate and sandstone in certain areas (e.g., Villa Juarez uplift in Durango and the Sierra Madre Oriental southwest of Monterrey) indicate local rapidly rising land masses. The presence of considerable shale and organic matter suggests that the climate on the surrounding land areas was somewhat less arid than during the Oxfordian. A minor regression of the Mexican sea during the Tithonian stage is apparently reflected in the off-shore deposits by the whitish, ashy appearance of the shaly and marly limestones of the highest Jurassic unit (Imlay, 1938a, pp. 1660, 1661).

FOSSILS

Localities.—SIERRA DE PARRAS, COAHUILA: The positions of the fossil localities in the Sierra de Parras are indicated in published papers (Imlay, 1936, fig. 3; 1937, fig. 3).

Locality 43: Right bank of Cañón de la Casita, about three-quarters of a mile north of Rancho La Casita. Fossils occur in limestone concretions in black shale in upper 83 feet of measured section (Imlay, 1937, p. 602). Represents beds with *Glochiceras fialar* and *Waagenia*.

Locality 46: On trail 3½ miles up Cañón del Organo. Fossils occur in limestone lenses in carbonaceous shale. Represents beds with *Mazapilites*.

Locality 53: One mile northwest of Rancho La Casita and half a mile west of Cañón de la Casita. Fossils occur in six inches of dark gray friable sandstone about 38 feet above base of La Casita formation. Probably represents upper Oxfordian.

Locality 57: About 450 yards east of Cañón de la Casita near the mouth of Cañón del Buey and on south flank of an anticline. Fossils occur in limestone concretions about 50 feet below the top of the formation. Represents beds with *Mazapilites*.

MOUNTAINS WEST OF LAGUNA DISTRICT, DURANGO: The Jurassic fossil localities are indicated on a published map (Kellum, 1936, pl. 14).

Locality J-2: About 3½ miles south-southwest of Las Cuevas Ranch. Fossils occur in sandstone unit near middle of measured section of La Casita formation (Kellum, 1936, p. 1054, pl. 13) about 8 feet above A-7.

Locality J-5: Isolated hill about 2 miles west-southwest of Las Cuevas Ranch.

LocalityJ-6: Cuesta on south side of entrance of Cañón Maravillas, about 2 miles southwest of Las Cuevas Ranch (Kellum, 1936, p. 1066).

Locality A-6: About 3½ miles south-southwest of Las Cuevas Ranch. At base of measured section of unit C (Kellum, 1936, pp. 1054, 1067) and about 190 feet above base of La Casita formation.

Locality A-7: About 3½ miles south-southwest of Las Cuevas Ranch. Sandstone bed on hillside about 185 feet higher stratigraphically than A-6.

Locality A-8: About 2⅓ miles south of Las Cuevas Ranch at base of Cuesta del Carbonera and on west side of trail to Picardias. Fossils occur in a coarse conglomerate about 368 feet below top of La Casita formation (Kellum, 1936, pp. 1054, 1067).

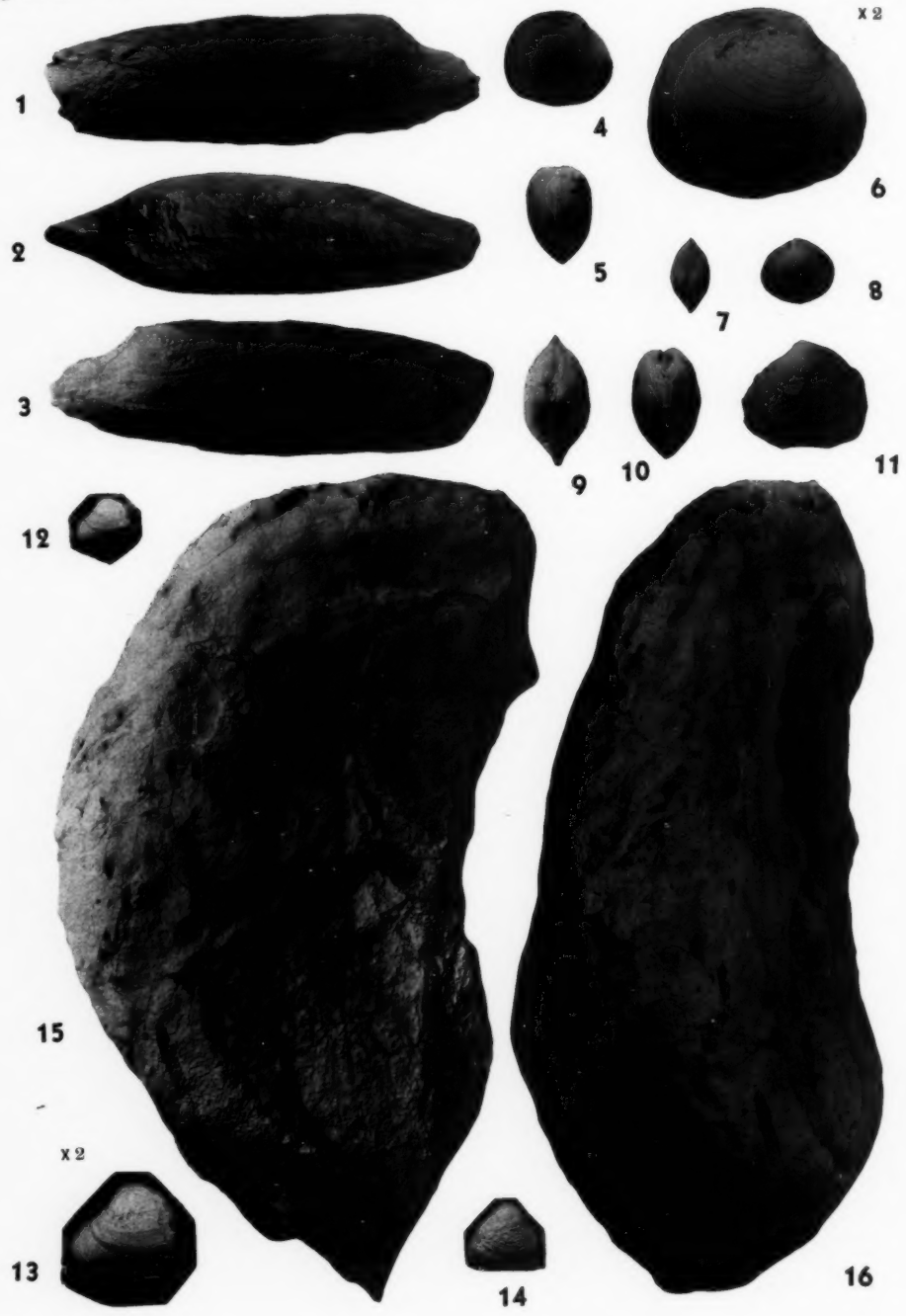
Locality A-13: Isolated knoll opposite the mouth of Cañón Maravillas about 2¼ miles southwest of Las Cuevas Ranch. Fossils occur in sandstones about 50 feet above base of La Casita formation.

Locality A-14: Sandstone ridge about 2¼ miles south-southwest of Las Cuevas Ranch and about half a mile south of Cañón Maravillas (Kellum, 1936, p. 1055, pl. 13). Fossils occur about 72 feet stratigraphically above

EXPLANATION OF PLATE 50

FIGS. *1–3—Exogyra* cf. *E. potosina* Castillo and Aguilera. Left valve, anterior view, and right valve of specimen U. M. 19313, ×1, locality A-8, Villa Juarez uplift, Durango. (p. 403)

Imlay, Upper Jurassic Pelecypods



Imlay, Upper Jurassic Pelecypods

TABLE 1.—GEOGRAPHIC DISTRIBUTION OF UPPER JURASSIC PELECYPODS IN NORTHERN AND EASTERN MEXICO

Species	Sierra de Parras				Mountains west of Laguna district, Villa Juarez uplift, Durango												Sierra del Chivo, Cañon del Toboso, Durango					Sierra de Mazapil						Sierra Jimulco	
	Locality 43	Locality 46	Locality 53	Locality 57	Locality J-2	Locality J-5	Locality J-6	Locality A-6	Locality A-7	Locality A-8	Locality A-13	Locality A-14	Locality A-19	Locality A-20	Locality A-33	Collection 8	Collection 9	Collection 10	Collections 12, 15	Collection 18	Camino Colorines	Cuesta del Gato	Puerto Blanco	Sierra de la Ventura	Escondida-Soledad, N.L.	Sierra de Catorce	Locality K-87	Locality K-92
Nucula? antiqua Imlay				×																								
Grammatodon crassilineatus Imlay				×												×												
delicatulus Imlay				×														×					×					
reticulatus Imlay													×															
sp.																						×						
Trigonia calderoni (Castillo and Aguilera)								×					×													×	×	
munita Cragin																												×
vyschetzkii Cragin								×			×																×	
sp. aff. *proscabra* Cragin																												
sp.				×																								
Cucullaea catorcensis (Castillo and Aguilera)																										×		
Ostrea sp.								×	×																			
Gryphaea cf. *mexicana* Felix														×														
sp.			×																									
Exogyra cf. *potosina* (Castillo and Aguilera)								×		×																		
Aucella sp. (various)																					×	×		×	×			
Pseudomonotis tamaulipana Imlay																								×				
aff. *tamaulipana* Imlay			×																									
durangensis Imlay						×	×					×			×													
cf. *durangensis* Imlay			×																									
Aulacomyella neogeae Imlay																												
Pinna quadrifrons Cragin?											×				×								×					
Astarte malonensis Cragin								×					×														×	×
? gracilicostula Imlay	×			×															×		×		×					
? zacatecana Imlay		×																×			×	×	×					
n. sp. ind.																					×							
sp.																					×							
Arctica coteroi (Castillo and Aguilera)																							×					
cf. *coteroi* (Castillo and Aguilera)			×																							×		
Lucina concaviuscula Imlay																							×					
potosina Castillo and Aguilera				×																×			×					
coetoi Castillo and Aguilera																										×		
sp.			×																				×					
Solenomorpha? jurassica Imlay								×																				
n. sp. ind.								×																				
Eocallista? cf. *cuneovatus* Cragin	×	×		×																								
Pleuromya? inconstans Castillo and Aguilera								×			×		×	×												×	×	×
sp.					×																							
Pholadomya paucicosta Roemer? (Cragin)						×					×																	
cf. *tosta* Cragin																												×
Cercomya durangensis Imlay											×																	

EXPLANATION OF PLATE 51

FIGS. *1–3*—*Solenomorpha? jurassica* Imlay, n. sp. Lateral and dorsal views of holotype U. M. 15931, locality A-6, Villa Juarez uplift, Durango. (p. 407)

4–11—*Astarte? zacatecana* Imlay, n. sp. *4–6*, Lateral and anterior views of holotype U. M. 19342, (*6*, ×2), Cuesta del Gato near Mazapil, Zacatecas; *7*, *8*, dorsal and lateral views of paratype U. M. 19356 Puerto Blanco near Mazapil, Zacatecas; *9-11* dorsal, anterior, and lateral views of paratype U. M. 19352 (internal mold), Puerto Blanco near Mazapil, Zacatecas. (p. 406)

12–14—*Astarte? gracilicostula* Imlay, n. sp. *12*, *13*, Holotype U. M. 21036, (*13*, ×2) collection 15 of Cañón del Toboso section, Sierra del Chivo, Durango; *14*, paratype U. M. 21034, locality 43, Sierra de Parras, Coahuila. (p. 407)

15, *16*—*Exogyra* cf. *E. potosina* Castillo and Aguilera. Views of left valve of specimen U. M. 17629, Locality A-8, Villa Juarez uplift, Durango. (p. 403)

All figures natural size unless otherwise indicated.

the locality of collection A-16, which probably represents the middle Oxfordian (Imlay, 1939, pp. 15, 21).

Locality A-19: On northwest end of ridge about 1¾ miles southwest of Las Cuevas Ranch. Fossils occur in sandstone about 130 feet below top of La Gloria formation.

Locality A-20: Isolated hill about three-quarters of a mile north of mouth of Cañón Maravillas and 1¾ miles southwest of Las Cuevas Ranch.

Locality A-33: Isolated sandstone knoll on north side of Mazatlan highway west of Lerdo near kilometer post 719.

Sierra del Chivo, Durango: This locality has been described in detail by Imlay (1939, pp. 9, 10, figs. 1, 4). Fossils occur in La Caja formation, which outcrops on the north wall of Cañón del Toboso about 2½ miles east of Symón, Durango.

Sierras de Mazapil, Zacatecas: The fossil localities near Mazapil have been indicated on geologic maps by Burckhardt (1906) and have been listed by Imlay (1939, pp. 10–12).

Sierra de la Ventura, Coahuila: East front of mountain about 6 miles southwest of La Ventura. Fossils obtained from limestone concretions in black shale about 40 feet above base of La Caja formation and one mile south of Mina de San Francisco (Imlay, 1939, p. 13).

Sierra Madre Oriental: Road from La Escondida to Soledad, Nuevo León, 7 miles (11.2 km.) from La Escondida, and 100 yards up small arroyo south of road.

Sierra de Jimulco, Coahuila: Fossil collections were made in Cañón de Agua Prieta about 2 miles southeast of Mina de los Chinos and about midway between the axes of the Viesca and Cañónes anticlines. Fossils occur in yellowish-gray quartzitic sandstone. Locality K-92 occurs about 100 yards farther up the canyon than locality K-87 (Kellum, 1932, fig. 5).

State of preservation.—The Upper Jurassic pelecypods of the Villa Juarez uplift and the Sierra de Jimulco are preserved in yellowish to grayish quartzitic sandstones and are more or less strongly deformed. Those from the Sierras de Parras, Mazapil, and the Sierra Madre Oriental occur in a sandstone or calcareous shale matrix, retain much of their shells, and are little deformed. Those from the Sierra de la Ventura occur in limestone concretionary masses and are preserved mainly as distorted internal molds with fragments of shell adhering. In the Cañón del Toboso section of the Sierra del Chivo they occur as internal molds and as flattened external casts.

Environment.—The Upper Jurassic pelecypods of Mexico occur in both near-shore and off-shore facies but are abundant only in the former. Near-shore facies of sandstone or sandy shale are characterized by thick-shelled species of *Trigonia*, *Exogyra*, *Pleuromya*, *Astarte*, *Pholadomya and Gryphaea*, and by scarcity of ammonites. The off-shore and the least clastic units of near-shore facies contain thinner-shelled species of *Pseudomonotis*, *Lucina*, *Grammatodon*, *Arctica*, *Astarte*, and *Aucella*, which are much subordinate in numbers to the asso-

Table 2.—Taxonomical and Numerical Distribution of Mexican Jurassic Pelecypods

Family	Genus	Number of species
Nuculidae	*Nucula*	1
Parallelodontidae	*Grammatodon*	4
	Cucullaea	1
Pinnidae	*Pinna*	1
Ostreidae	*Ostrea*	1
	Gryphaea	2
	Exogyra	1
Trigoniidae	*Trigonia*	5
Pteriidae	*Aucella*	many
	Pseudomonotis	4
	Aulacomyella	1
Astartidae	*Astarte*	5
Arcticidae	*Arctica*	1
Lucinidae	*Lucina*	4
Solenopsidae	*Solenomorpha?*	2
Veneridae	*Eocallista?*	1
Pleuromyidae	*Pleuromya?*	2
Pholadomyidae	*Pholadomya*	2
Laternulidae	*Cercomya*	1

TABLE 3.—KNOWN RANGES OF UPPER JURASSIC PELECYPODS OF MEXICO

Species	Oxfordian		Kimmeridgian				Portlandian	Tithonian
	Middle	Upper	*Idoceras* beds	*Waagenia* beds	*Mazapilites* beds	Zone uncertain	*Durangites* and *Kossmatia* beds	*Substeueroceras* and *Proniceras* beds
Nucula? antiqua Imlay					×			
Grammatodon crassilineatus Imlay					×			
delicatulus Imlay			×		×			
reticulatus Imlay		×						
Trigonia calderoni (Castillo and Aguilera)		×	×					
munita Cragin		×						
vyschetzkii Cragin			?			×		
Gryphaea cf. *mexicana* Felix			?			×	×	
Exogyra cf. *potosina* Castillo and Aguilera			?		?		×	
Pseudomonotis tamaulipana Imlay			×					
durangensis Imlay		×			?			
Aulacomyella neogeae Imlay			×					
Pinna cf. *quadrifrons* Cragin			×		?		×	
Astarte malonensis Cragin		×	×				×	
? gracilicostula Imlay			×		×			
? zacatecana Imlay			×		×			
Arctica coteroi (Castillo and Aguilera)			×				×	
Lucina concaviuscula Imlay			×					
potosina Castillo and Aguilera			×		×		?	
Solenomorpha? jurassica Imlay			×					
Eocallista? cf. *cuneovatus* Cragin					×			
Pleuromya? inconstans Castillo and Aguilera		×	×				×	
Pholadomya paucicosta Roemer?(Cragin)			?			×	×	
Cercomya durangensis Imlay			?			×	×	

ciated ammonites. The seas must have been very shallow, as is indicated by the presence of pelecypods and of marls and shales in the off-shore deposits of the central part of the Mexican geosyncline. Evidence has been given elsewhere (Burckhardt, 1930, p. 165; Imlay, 1936, p. 1146; 1937, p. 629; 1938c, p. 548) which suggests that the land areas north of the Mexican sea had an arid climate during the Oxfordian stage of the Jurassic and the Neocomian stages of the Lower Cretaceous. The intervening stages of the Upper Jurassic were probably less arid, as is indicated by the deposition of large quantities of carbonaceous and bituminous muds in the sea and of coal beds around its margin.

Biological analysis.—Table 1 shows the known occurrences of Upper Jurassic pelecypods in northern and eastern Mexico. The data, except for the Sierra de Catorce, are based on collections in the Museum of Paleontology at the University of Michigan. Omitting the *Aucellas*, which were not studied by the writer, the fauna includes about 40 species, of which 12 are new and 9 are not named specifically. The apparent poverty in species as compared with the Malone fauna of western Texas is ascribed to less thorough collecting. Of particular interest is the occurrence of *Aulacomyella* which is like the Triassic genus *Halobia* but is known only from Upper Jurassic strata. Another form is referred provisionally to *Solenomorpha*, although that genus has not been recorded in strata younger than Triassic. An evaluation of families, genera, and species is shown in table 2.

Correlation.—Correlations of the Upper Jurassic beds of Mexico with the European

sections are based on short-lived ammonite genera and species (Burckhardt, 1930, pp. 105–114; Imlay, 1939, pp. 21–24). The associated, longer-lived pelecypods are not only much less useful for intercontinental correlations, but some authorities have misinterpreted their age as Cretaceous (Kitchin, 1926, pp. 454–469). The argument for a Cretaceous age was based on the fact that certain types, particularly of *Trigonia*, had not been found previously in strata older than Cretaceous. The various views have been amply discussed by Baker, Dane, and Reeside (1936, pp. 61–62). The present work shows that most of the pelecypod species of the Malone fauna, and in particular the species that Kitchin cited as of Cretaceous age, occur in Mexico in deposits of undoubted Upper Jurassic age ranging from Upper Oxfordian to Portlandian. This evidence supplements and confirms the conclusions of Cragin (1905, pp. 19–20) and Albritton (1938, pp. 1762–1764) concerning the age of the Malone pelecypod fauna.

Whether the Upper Jurassic deposits of the Mexican geosyncline can be subdivided on the basis of pelecypods, as it has been on ammonites, is not known at present because of insufficient data on the ranges of the pelecypod species. Some work of this nature has been attempted by Albritton (1938, pp. 1761–1762) for the fauna of the Malone formation of west Texas. Table 3 shows the known ranges of the Mexican species, although many of them may have greater ranges than indicated.

SYSTEMATIC DESCRIPTIONS

Genus NUCULA Lamarck, 1799

NUCULA? ANTIQUA Imlay, n. sp.

Plate 56, figures 3–6

The species is represented by one internal mold, which bears fragments of shell material. Shell small, ovate-trigonal in outline, thin, equivalve, inequilateral. Beaks approximate, inclined posteriorly, situated about 0.6 the length of the shell from the anterior extremity. Posterodorsal margin regularly rounded and steep, anterodorsal margin gently convex and long; anterior margin narrowly rounded; posterior margin steep, subangular at lower extremity; ventral margin long and gently convex. Surface nearly smooth, marked by weak, concentric, nearly microscopic growth lines near the ventral margin. Pseudolunule bounded by weak ridges. Internal characters unknown.

Dimensions of holotype: length, 8.2 mm.; height, 5 mm.; thickness of both valves, 3.3 mm.

Type.—Holotype 16970, Museum of Paleontology, University of Michigan.

Occurrence.—La Casita formation (*Mazapilites* beds), locality 57, Sierra de Parras, Coahuila.

Genus GRAMMATODON Meek and Hayden, 1860

GRAMMATODON DELICATULUS Imlay, n. sp.

Plate 53, figures 22–25

The species is represented by 17 specimens of which five retain large portions of the shell, four are external casts, one is an external mold, and seven are internal molds.

Shell subquadrate, strongly convex, most inflated slightly above the midheight. Beaks prominent, curved inward and forward, not contiguous, situated about 0.4 the length of the shell from the anterior extremity. A pronounced umbonal ridge extends from the beak to the lower posterior extremity and causes the posterodorsal surface to lie at nearly right angles to the median surface. Posterodorsal surface slightly concave. Anterior margin meeting the hinge line at nearly a right angle but diverging obliquely backward below; ventral margin gently convex, passing gradually into the anterior margin, rounding abruptly into the posterior margin at slightly less than a right angle; posterior margin nearly straight, fairly long, inclined slightly backward from the hinge line. Surface marked by numerous fine radial ribs of two sizes, by weaker, concentric growth lines, and by low concentric growth undulations toward the ventral margin. The set of stronger radial ribs begin on the umbo; are closely spaced on the umbo and posterodorsal surface; diverge somewhat and become stronger toward the ventral margin; diverge widely and become markedly stronger toward the anterior margin. Near the ventral margin the major ribs are separated by one to three finer intercalary ribs. No examples of bifurcating ribs have been noted.

Cardinal area long and narrow. Hinge

plate (partially exposed on one specimen) long and straight, with six or seven short, narrow, oblique, parallel anterior teeth and two long narrow posterior teeth, which extend somewhat over half the length of the hinge line. Interior of valve without a raised plate for either adductor muscle.

Dimensions of holotype: length 27 mm.; height, 18.7 mm.; thickness of one valve, 8.2 mm.

Remarks.—The species is characterized by its prominent umbonal ridge and its fine radial ribs, which are closely spaced on the posterior and ventral surfaces but widely spaced on the anterior surface.

Type.—Holotype 21021, paratypes 19254, 19247, 21022, Museum of Paleontology, University of Michigan.

Occurrence.—La Casita formation (*Mazapilites* beds), locality 57, Sierra de Parras, Coahuila; La Caja formation (*Idoceras* beds), Camino de los Colorines and Puerto Blanco near Mazapil, Zacatecas; La Caja formation (*Mazapilites* beds), collections 8 and 10 of Cañón del Toboso section, Durango.

GRAMMATODON CRASSILINEATUS
Imlay, n. sp.
Plate 53, figures 16–19

The species is represented by five specimens. Shell subquadrate, most inflated slightly above the midheight, strongly convex. Beaks fairly prominent, curved inward and forward, not contiguous, and situated about 0.4 the length of the shell from the anterior extremity. A pronounced umbonal ridge extends from the beak to the lower posterior margin. Posterodorsal surface slightly concave. Anterior margin meeting the hinge line at nearly a right angle, then diverging obliquely backward below and passing gradually into the gently convex ventral margin; posterior margin nearly straight, fairly long, inclined slightly backward from the hinge line, rounding abruptly into the ventral margin. Surface marked by a number of fine radial ribs of two sizes, by weaker concentric growth lines, and by low concentric growth undulations toward the ventral margin. The set of stronger radial ribs are fairly widely spaced on the median and posterior surfaces and become much stronger and wider-spaced on the anterior surface. Successive strong ribs are separated by one to three intercalary ribs, which begin on the umbo and remain faint throughout their extent. Hinge plate and internal features unknown.

Dimensions of holotype: length, 26 mm.; height, 18 mm.; thickness of one valve, 8.5 mm.

Remarks.—This species may be distinguished from *G. delicatulus* Imlay by its coarser, wider-spaced radial ribbing and by its slightly less pronounced umbonal ridge.

Type.—Holotype 21006, paratypes 19246, 19298, Museum of Paleontology, University of Michigan.

Occurrence.—La Casita formation (*Mazapilites* beds), locality 57, Sierra de Parras, Coahuila; La Caja formation (*Mazapilites* beds), collections 8, 9, 10, and 18 in the Cañón del Toboso section, Durango.

GRAMMATODON RETICULATUS
Imlay, n. sp.
Plate 53, figures 20, 21

The species is represented by one specimen. Shell subquadrate, most inflated on the umbo, fairly strongly convex. Umbo broad, moderately prominent. Beaks curved inward and forward, situated about 0.4 the length of the shell from the anterior extremity. An angular umbonal ridge extends from the beak to the lower posterior extremity. Posterodorsal surface concave. Anterior margin inclined backward from hinge line; ventral margin gently convex, rounding evenly into the anterior margin, rounding abruptly at a subacute angle with the posterior margin; posterior margin nearly straight, moderate in length, inclined backward from hinge line. Surface marked by a single set of moderately strong radial ribs and by slightly weaker concentric ribs, whose intersections produce a reticulate appearance. Interspaces a little wider than ribs, especially near the anterior margin. Hinge and internal features unknown.

Dimensions of holotype: length, 21 mm.; height, 14.5 mm.; thickness of one valve, 5 mm.

Remarks.—This species may be distinguished from associated species of *Grammatodon* in the Upper Jurassic beds of Mexico by its reticulate sculpture and angular umbonal ridge.

Type.—Holotype 15860, Museum of Paleontology, University of Michigan.

Occurrence.—La Gloria formation, locality A-19, a quarter of a mile north of Cañón Maravillas, about 2 miles southwest of Las Cuevas, Durango.

Genus TRIGONIA Bruguière, 1789

TRIGONIA CALDERONI (Castillo and Aguilera)

Plate 55, figure 8

Goniomya calderoni Castillo and Aguilera, *1895*, Com. Geol. Mexico, Bol. 1, p. 9, pl. 5, figs. 17, 18.

Trigonia calderoni Cragin, *1905*, U. S. Geol. Survey, Bull. 266, p. 59, pl. 9, figs. 4–6.

Remarks.—The species is represented in the University of Michigan collections by 11 specimens, of which the largest is illustrated. Although its anterior margin is partly defective, its dimensions are about as follows: length, 81 mm., height, 52 mm., thickness of one valve, 18 mm.

Hypotype.—21142, Museum of Paleontology, University of Michigan.

Occurrence.—In Mexico from La Casita formation at locality A-6 and La Gloria formation at locality A-19, Villa Juarez uplift, near Las Cuevas, Durango; La Gloria formation at locality K-92, Sierra de Jimulco, Coahuila; La Caja formation, Arroyo de Alamitos, Sierra de Catorce, San Luis Potosí.

TRIGONIA VYSCHETZKII Cragin

Plate 54, figure 9

Trigonia vyschetzkii Cragin, *1893*, Geol. Survey Texas, Fourth Ann. Rept., pt. 2, p. 215.

Trigonia vyshetzkii Cragin *1905*, U. S. Geol. Survey, Bull. 266, p. 56, pl. 8, figs. 1, 2, pl. 9, figs. 1–3.

Remarks.—The figured specimen is a highly nodose form like that figured by Cragin (1905, pl. 8, fig. 1, pl. 9, fig. 3) but is about twice as large. Its ventral margin is defective.

Hypotype.—21153, Museum of Paleontology, University of Michigan.

Occurrence.—In Mexico from La Casita formation at localities A-6 and A-13 near Las Cuevas, Durango; La Gloria formation at locality K-92, Sierra de Jimulco, Coahuila.

TRIGONIA MUNITA Cragin

Plate 56, figures 1, 2

Trigonia munita Cragin, *1905*, U. S. Geol. Survey, Bull. 266, p. 62, pl. 10, figs. 8–11.

This species is represented from Mexico by eight specimens whose earliest formed parts possess a shape and ornamentation identical with the figured types of Cragin. As some of the Mexican specimens are more nearly adult than the types, the species will be redescribed as follows:

Shell large, ovate-pyramidal to elongate-trigonal, highly convex. Umbones produced, pointed, and considerably incurved. Anterior end produced, rounding evenly into ventral margin and thereby forming a curve, which varies in convexity on different specimens.

Escutcheon fairly large, slightly concave, ornamented with oblique riblets, which become stronger posteriorly. Inner carina moderately prominent. Area flattened but elevated above the escutcheon; subdivided by a median furrow; ornamented with five or six unequal reticulated radial ribs, which are narrow and elevated anteriorly but become broad and indistinct posteriorly as the concentric ribs become stronger. Marginal carina large and prominent, separated from the pre-areal surface of the left valve by a deep furrow.

Pre-areal (anterior) surface ornamented with 25 to 35 strong concentric ribs, which are separated by somewhat wider interspaces and parallel the ventral margin of the shell. These ribs terminate almost abruptly at the pre-areal furrow of the left valve and at the marginal carina of the immature part of the right valve.

The Mexican specimens are so distorted that measurements are useless, but some of the apparent variation in height, length, and convexity is probably due to variation in the species.

Hypotype.—21197, Museum of Paleontology, University of Michigan.

Occurrence.—La Gloria formation, Locality K-92, Sierra de Jimulco, Coahuila.

Genus GRYPHAEA Lamarck, 1801

GRYPHAEA cf. G. MEXICANA Felix

Plate 54, figures 1–7

The species is represented by 28 fairly well preserved specimens from eastern Durango. Shell rather small, varying from subovate to obliquely ovate in outline. Shell wall fairly thick. Left valve moderately convex. Most specimens marked by a sulcus,

which extends from the beak obliquely backward and downward, producing a wing-like extension or flare of the posteroventral margin. On some specimens the sulcus is situated nearly medially, and the posteroventral flare is weak. On a few specimens the sulcus is situated toward the anteroventral margin. One specimen bears sulci on both margins. Beak incurved, fairly prominent, generally situated back of the midlength. Surface marked with concentric growth lines and undulations, which are produced dorsally where they pass over the sulci. Umbonal region of one specimen (U. M. 21192) exhibits fine radiating lines. Dimensions highly variable but usually higher than long.

Right valve irregularly flattened to concave, partly overlapped by margins of left valve. Surface marked by weak concentric growth lines.

Hinge small, ligamental pit triangular, subequilateral, shallow. Adductor scar relatively small, subcircular, moderately impressed; situated below the midheight and a little back of the midlength of the shell.

Remarks.—The Mexican specimens described above probably belong to *G. mexicana* Felix (1891, p. 178, pl. 27, figs. 30, 30a), but exact identity will be uncertain until the holotype or specimens from the type locality can be examined. The writer examined the Texas specimens which Cragin (1905, p. 39, pl. 3, figs. 1–6) assigned to *G. mexicana* Felix and is certain that they represent the same species as occurs in eastern Durango. The species, both in Texas and Durango, shows considerable variation in the convexity of the left valve, in the prominence and dorsal projection of the umbo, in the development of a concavity on the posterodorsal margin, in the position of the sulci, and in the elongation of the posteroventral margin.

Figured specimens.—21146–21151, Museum of Paleontology, University of Michigan.

Occurrence.—La Casita formation, locality A-20, Villa Juarez uplift, southwest of Las Cuevas, Durango.

Genus EXOGYRA Say, 1820

EXOGYRA cf. E. POTOSINA Castillo and Aguilera

Plate 50, figures 1–3; plate 51, figures 15, 16

In the Upper Jurassic deposits of Mexico occurs a highly variable species of *Exogyra* which may belong in *E. potosina* Castillo and Aguilera (1895, p. 3, pl. 2, fig. 9), but which cannot be positively identified with the latter on the basis of published description and figures. The forms from the Malone formation of Texas which Cragin (1905, pp. 41–43, pl. 3, fig. 7, pl. 4, fig. 9) called *E. potosina*, are preserved mainly as internal molds with small fragments of shell adhering. They greatly resemble the clay squeezes of the interiors of left valves of the Mexican forms described herein, but specific identification on these resemblances is not justified. The forms in the University of Michigan collections may be described as follows:

Shell of adult inequivalve, thick, narrowly to broadly subovate in outline. Left valve much larger than right valve, highly but variably convex. Apical portion strongly incurved and bent moderately to strongly laterally. An extremely pronounced, rounded nodular umbonal ridge extends from the beak backward in a curve conforming with the twist of the shell and becoming lower and broader posteriorly. The anterior side of the valve is steeper than the posterior side and toward the umbonal region of adult specimens becomes overhanging. Character of hinge unknown. Adductor scar broadly oval in outline, situated near the midheight and a little in front of the midlength of the shell. Surface marked by low concentric growth lines.

Right valve operculiform, elongate, concave; beak depressed, twisted; posterior margin depressed to the margin of the left valve; anterior margin thick, with an elevated crest; surface marked by low concentric growth lines.

Dimensions in mm. are as follows:

Specimen	Length	Estimated height	Longest dimension	Approximate thickness
U.M. 17629	52	210	122	64
U.M. 19313	67	190	115	50

Remarks.—The species shows all variations from narrow forms with extremely high umbonal ridges and little lateral curvature of the beak (pl. 51, figs. 15, 16) to fairly broad forms with somewhat lower umbonal ridges and considerable lateral curvature of the beak. A moderately broad form is shown on pl. 50, figs. 1–3. The species is easily distinguished from *Exogyra reedi* Imlay, which characterizes the Mexican Neocomian, by its umbonal ridge, which is much higher and is rounded instead of angular.

Figured Specimens:—17629, 19313, Museum of Paleontology, University of Michigan.

Occurrence.—La Casita formation, localities A-6 and A-8, a few miles south of Las Cuevas, Durango.

Genus PSEUDOMONOTIS Beyrich, 1862

PSEUDOMONOTIS DURANGENSIS
Imlay, n. sp.
Plate 53, figures 1–4, 8–10

The species is represented by about 60 specimens, which are more or less distorted but otherwise well preserved.

Shell small, rounded to ovate, inequivalve, inequilateral, left valve fairly convex, right valve gently convex. Umbo of left valve more prominent than umbo of right. Beaks rather pointed, curved inward and slightly forward, projecting above hinge line, and situated slightly anterior to midlength of shell. Beak of right valve smaller and less projecting than beak of left valve. Margins rounded, inclined outward from the hinge line, which is about three-fifths as long as the shell. Main surface of left valve marked by variably strong, threadlike radiating ribs and by much weaker concentric ribs, which are produced into lamellae where they pass over the radial ribs. New ribs arise by implantation. Interspaces flat and about twice as wide as radial ribs. Anterodorsal and posterodorsal surfaces only faintly ornamented. Extremity of left beak smooth for a distance of 2 to 3 mm.

Surface of right valve less strongly ribbed than left valve, with early smooth stage persisting about three times as long.

Posterior ear fairly short, winglike, weakly ornamented, and separated from main body of shell by a depressed area. Anterior ear rudimentary.

Inner surface smooth above, marked with radiating lines toward the ventral margin. A large adductor scar clearly impressed a little below the midheight and back of the midlength of the shell.

Dimensions in mm. are as follows:

Specimen	Length	Height	Thickness of one valve
Holotype 21018 (left valve)	27	25	8
Paratype 21015 (left valve)	?	23	7
Paratype 21017 (left valve)	?	25	8.5
Paratype 21025 (left valve)	15	16	5.5
Paratype 21020 (right valve)	25	21	5.5
Paratype 21024 (right valve)	18.5	15	3.5

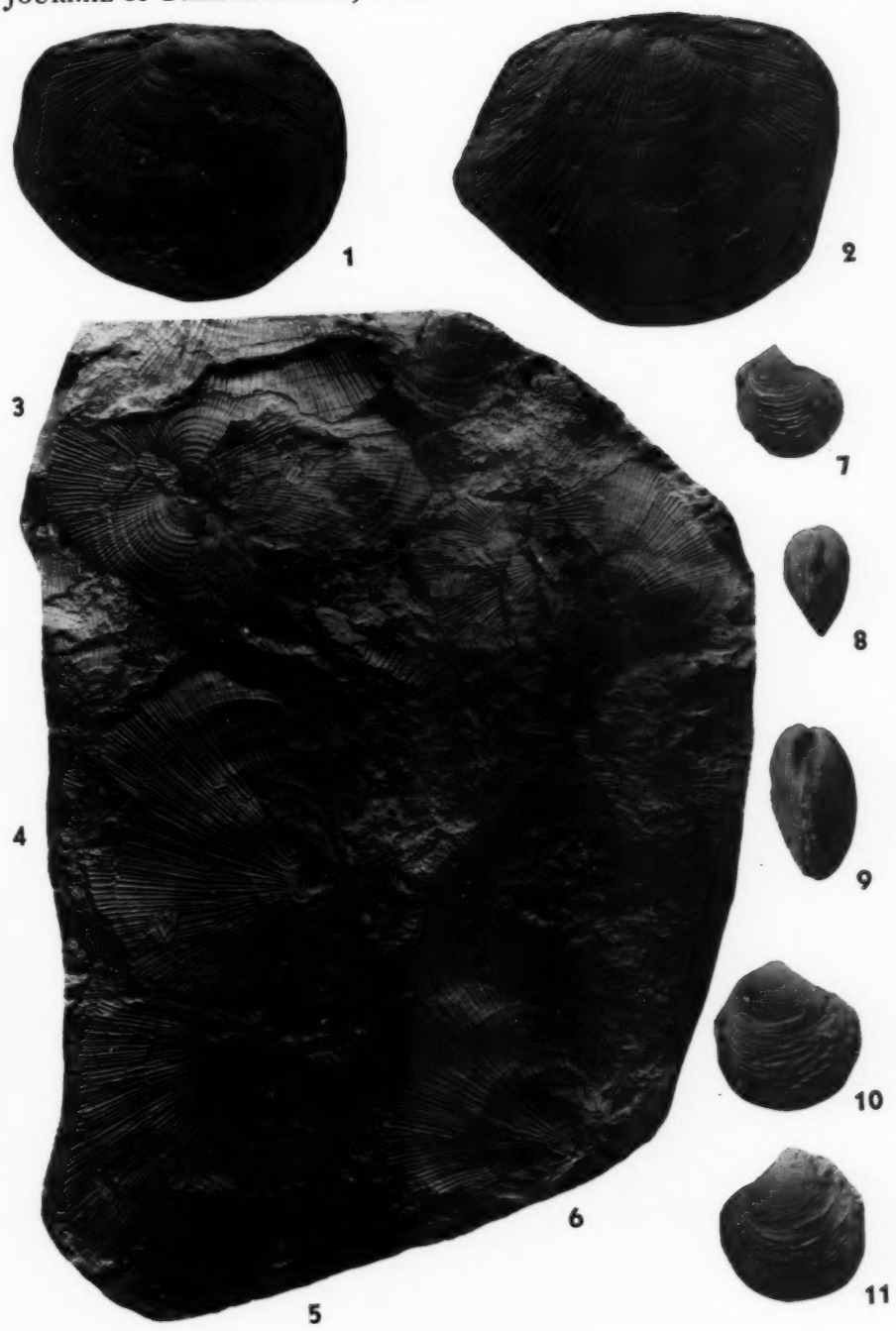
Remarks.—The species attains a size about half again as large as the holotype and shows considerable variation in shape, convexity, and strength of ribbing. It may be distinguished from *P. tamaulipana* Imlay, n. sp., by its coarser, more widely spaced ribs and the greater convexity of its right valve.

EXPLANATION OF PLATE 52

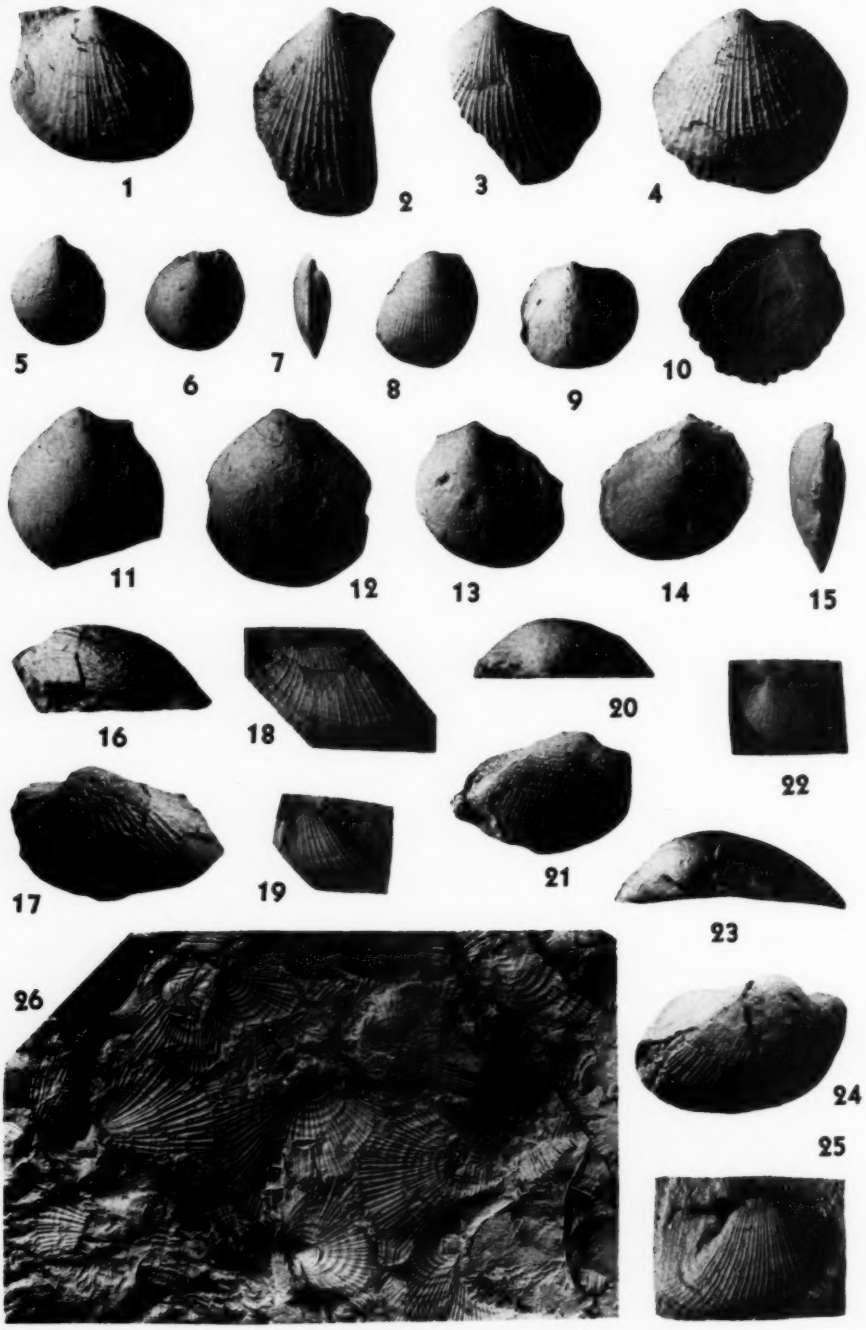
FIGS. *1–6—Aulacomyella neogeae* Imlay, n. sp. *1, 4,* Clay squeeze and external mold of holotype U. M. 21124; *2,* 5, clay squeeze and external mold of paratype U. M. 21125; *3,* crushed valves of external cast of paratype U. M. 21127; *6,* external mold of paratype U. M. 21126, 11.2 km. from Escondida on road to Soledad, Nuevo León. (p. 405)

7–11—Lucina concaviuscula Imlay, n. sp. *7, 8,* Lateral and posterior views of paratype U. M. 19361, Puerto Blanco near Mazapil, Zacatecas; *9–11,* anterior and lateral views of holotype U. M. 19348, one mile south of Mina de San Francisco, Sierra de la Ventura, Coahuila. (p. 408)

All figures natural size.



Imlay, Upper Jurassic Pelecypods



Imlay, Upper Jurassic Pelecypods

Type.—Holotype 21018, paratypes 21019, 21020, 21015, 21017, 21023–21025, Museum of Paleontology, University of Michigan.

Occurrence.—La Gloria formation, at localities J-5, J-6, A-14, and La Casita formation at A-33 in the mountains west of the Laguna District, eastern Durango.

Pseudomonotis tamaulipana
Imlay, n. sp.
Plate 53, figures 5–7, 11–15

The species is represented by about 40 specimens, of which most are well preserved and little distorted. In some specimens the valves have not been appreciably separated.

Shell small, ovate to obliquely ovate, inequivalve, inequilateral, left valve strongly convex, right valve gently convex. Umbo of left valve much more prominent than umbo of right valve. Beaks pointed, curved inward, projecting above the hinge line, and situated slightly anterior to midlength of shell. Beak of right valve much smaller and less projecting than beak of left valve. Margins rounded, inclined outward from the hinge line, which is a little more than half as long as the shell. Surface of left valve marked with many low, broad ribs of variable strength and with weaker concentric growth lines. Interspaces a little wider than ribs. New ribs arise by implantation. Ornamentation becomes slightly weaker on posterodorsal and anterodorsal surfaces and disappears on extremity of beak. Surface of right valve marked only by faint concentric growth lines until late stages of growth, radial ribs appearing at a distance of 8 to 10 mm. from the beak, but remaining faint. Posterior ear short, winglike, faintly ornamented, and separated from main body of shell by a depressed area. Anterior ear rudimentary. Inner surface smooth on right valve, marked with radial lines on left valve.

Dimensions in mm. are as follows:

Specimen	Length	Height	Thickness of left valve	Thickness of both valves
Holotype 21032	22.5	24.5	7.5	
Paratype 21030	21.5	23.5 (?)	6.5	
Paratype 21031	21	20	6	8+
Paratype 21029	13.5	15	3.5	5.5

Explanation of Plate 53

Figs. *1–4, 8–10—Pseudomonotis durangensis* Imlay, n. sp. *1*, Large right valve, paratype U. M. 21020; *2*, left valve, paratype U. M. 21017; *3*, left valve, paratype U. M. 21015; *4*, left valve, holotype U. M. 21018; *8*, left valve, paratype U. M. 21025; *9*, right valve, paratype U. M. 21024; *10*, interior of right valve, paratype U. M. 21019. Specimens represented by *1–4* and *10* are from locality J-5, by *8* and *9* are from locality A-14 in the Villa Juarez uplift, eastern Durango. (p. 404)

5–7, 11–15—Pseudomonotis tamaulipana Imlay, n. sp. *5–7*, Left and right valves and posterior view of paratype U. M. 21029; *11*, left valve, paratype U. M. 21030; *12*, left valve, holotype U. M. 21032; *13–15*, left and right valves and posterior view of paratype U. M. 21031. All specimens obtained 11.2 km. from La Escondida on road to Soledad, Nuevo León. (p. 405)

16–19—Grammatodon crassilineatus Imlay, n. sp. *16, 17*, Dorsal and lateral views of holotype U. M. 21006, locality 57, Sierra de Parras, Coahuila; *18*, paratype U. M. 19246, collection 10, Cañon del Toboso, Durango; *19*, paratype U. M. 19298, collection 9, Cañón del Toboso, Durango. (p. 401)

20, 21—Grammatodon recticulatus Imlay, n. sp. Dorsal and lateral views of holotype U. M. 15860, locality A-19, Villa Juarez uplift, eastern Durango. (p. 401)

22–25—Grammatodon delicatulus Imlay, n. sp. *22*, Paratype U. M. 19247, collection 10, Cañón del Toboso, Durango; *23, 24*, dorsal and lateral views of holotype U. M. 21021, locality 57, Sierra de Parras, Coahuila; *25*, paratype U. M. 19254, collection 10, Cañón del Toboso, Durango. (p. 400)

26—Aulacomyella neogeae Imlay, n. sp. Slab with numerous fragments (U. M. 17816) showing characteristic ornamentation, 11.2 km. from La Escondida on road to Soledad, Nuevo León. (p. 406)

All figures natural size.

Remarks.—This species is characterized by the fine, close-set ribbing of its left valve and by its nearly smooth right valve. A remarkably similar species has been obtained in northern Louisiana from Pardee Well C-1 (sec. 17, R. 23 N., T. 11 W.) at depths of 9470 to 9790 and in Sexton Well Unit no 1 (sec. 32, R. 23 N., T. 9 W.) at depths of 9415 to 9418. These occurrences are in the Cotton Valley formation, whose top was penetrated at 7935 in the Pardee C-1 well, and are over 3000 feet below the *Dufrenoya texana* zone.[1] The specimens of *Pseudomonotis* in the Cotton Valley formation perhaps have slightly coarser ribbing than *P. tamaulipana* Imlay, but this appearance may be due to their better condition of preservation.

Type.—Holotype 21032, paratypes 21029–21031, 21033, Museum of Paleontology, University of Michigan.

Occurrence.—La Casita formation (*Idoceras* beds), 7 miles (11.2 km.) from La Escondida about 100 yards south of road to Soledad, Nuevo León.

Genus AULACOMYELLA Furlani, 1910

AULACOMYELLA NEOGEAE Imlay, n. sp.

Plate 52, figures 1–6; plate 53, figure 26

Shells of medium size, obliquely ovate, longer than high, inequilateral, compressed. Beaks fairly prominent, projecting over the hinge line, incurved, situated nearly in the middle of the hinge line. Ears not apparent. Hinge line long and straight. Anterior and ventral margins regularly rounded, posterior margin somewhat prolonged. Beak region strongly wrinkled to a height of about 10 mm. Surface marked with fine radial ribs, by weaker concentric growth lines, and by growth undulations. The radial ribs are of variable size, are stronger on the posterior than on the anterior side, trend nearly straight from the beak to the outer margins, increase in number by intercalation, and are separated by somewhat wider interspaces.

Approximate dimensions of holotype: length 44 mm.; height 38 mm.; length of hinge line 29 mm.

Remarks.—The general appearance of the Mexican species recalls the Triassic genus *Halobia*. However, it is much more recent than *Halobia* and shows the characters that Furlani (1910, pp. 85–88, pl. 3 figs. 2 and 3) assigns to *Aulacomyella*, which occurs in the Upper Jurassic of Europe. According to Furlani, *Aulacomyella* is distinguished from *Halobia* by a shorter hinge line, by a stronger beak projecting above and somewhat over the hinge line, and by stronger rib bundles in the area extending from the beak to the posteroventral margin. Neither the European nor Mexican specimens of *Aulacomyella* show traces of ears. *A. neogeae* Imlay, n. sp., differs from *A. problematica* Furlani by its more nearly equilateral form, less developed concentric growth lines, and less prominent beak.

Type.—Holotype 21124, paratypes 21125–21127, Museum of Paleontology, University of Michigan.

Occurrence.—La Casita formation (*Idoceras* beds), 7 miles from La Escondida about 100 yards south of road to Soledad, Nuevo León; La Caja formation (*Idoceras* beds), Puerto Blanco near Mazapil, Zacatecas.

Genus ASTARTE Sowerby, 1817

ASTARTE? ZACATECANA Imlay, n. sp.

Plate 51, figures 4–11

The species is represented by 21 specimens, of which most are internal and external molds. The holotype lacks parts of the beaks but is nearly undeformed and retains most of its shell.

Shell subovate in outline, medium-sized, equivalve, inequilateral, fairly convex; most inflated slightly above the midheight. Umbones moderately prominent. Beaks moderate in size, incurved, prosogyrate, approximate, excavated anteriorly, situated from 0.3 to 0.4 the length of the shell from the anterior extremity. An indistinct umbonal ridge extends from the posterior side of the umbo to the posteroventral margin and is followed posteriorly by a faint depression. Dorsal margins slope from the beaks at an angle ranging from 115° to 125°, the anterodorsal slope being steeper than the posterior. Anterodorsal margin gently concave, posterodorsal margin convex; anterior margin regularly rounded; posterior margin broadly rounded; ventral margin gently

[1] Roy T. Hazzard, personal correspondence.

convex, rounding abruptly into the posterior margin at nearly a right angle, rounding gradually into the anterior margin. Surface marked by close-set, fine, raised, concentric ribs, which are somewhat irregular in strength and become coarsest ventrally. The holotype bears about 150 ribs between the ventral margin and the beak region. Hinge unknown. Lunule small and shallow. Escutcheon elongate. Adductor scars, as shown on internal mold, are fairly small, subequal, moderately impressed. Pallial line simple. Shell material of moderate thickness.

Dimensions in mm. are as follows:

Specimen	Length	Height	Thickness
Holotype U.M. 19342..	15.2	14	9.2
Paratype U.M. 19352..	17.5	15.3	9.4
Paratype U.M. 19356..	10.2	9.3	5.7

Remarks.—This species is characterized by its numerous fine concentric ribs. It is less elongate than *A. posticalva* Cragin (1905, p. 67, pl. 9, figs. 5, 6), has less pointed beaks, and many more ribs.

Type.—Holotype 19342, paratypes 19352, 19356, Museum of Paleontology, University of Michigan.

Occurrence.—La Casita formation (*Mazapilites* beds) at locality 46 in the Sierra de Parras, Coahuila; La Caja formation (*Idoceras* beds) at Puerto Blanco and divide west of Cuesta del Gato near Mazapil, Zacatecas; La Caja formation (*Idoceras* beds), Sierra de la Ventura, Coahuila; La Caja formation (*Mazapilites* beds), collection 10 in the Cañon del Toboso section, Durango.

ASTARTE? GRACILICOSTULA
Imlay, n. sp.
Plate 51, figures 12–14

The species is represented by 13 specimens, of which most are internal molds with fragments of shell adhering. The holotype (pl. 51, figs. 12, 13) best illustrates the ornamentation, but its posterior margin is imperfectly preserved.

Shell fairly small, subtrigonal, inflated, equivalve, inequilateral, most inflated slightly above the midheight. Umbones large, prominent. Beaks inclined forward and inward, approximate, situated about 0.4 the length of the shell from the anterior extremity. A faint obtuse ridge trends from the posterior side of the umbo to the posteroventral margin. Dorsal margins slope from the beaks at an angle ranging from 80° to 90°. Anterodorsal margin concave; posterodorsal margin gently convex and merging with posterior margin; anterior margin fairly narrowly rounded; ventral margin gently convex, rounding into the posterior margin at a subacute angle, rounding gradually into the anterior margin. Surface marked by close-set fine concentric ribs, which become stronger ventrally and vary somewhat in coarseness on different specimens. Near the ventral margin of the holotype occur 9 ribs in a space of 1 mm. Internal characters unknown.

Dimensions in mm. are as follows:

Specimen	Length	Height	Thickness of one valve
Holotype 21036.....	8.7(?)	8.2	3.0
Paratype 21034.....	9.7	9.4	3.0
Paratype 21035.....	9.6	9.2	3.2

Remarks.—This species may be distinguished from *A. zacatecana* Imlay by its inflated, subtrigonal form, relatively larger umbones, and slightly coarser ribbing. The holotype (pl. 51, figs. 12, 13) illustrates the finer ribbed forms, and paratype U. M. 21034 (pl. 51, fig. 14) illustrates the coarser ribbed forms. Corrosion of the latter specimen has over emphasized the coarseness of the ribbing.

Type.—Holotype 21036, paratypes 21034, 21035, Museum of Paleontology, University of Michigan.

Occurrence.—La Casita formation (*Mazapilites* beds), locality 43, Sierra de Parras, Coahuila; La Caja formation (*Idoceras* beds) at Camino de los Colorines and divide west of Cuesta del Gato near Mazapil, Zacatecas; La Caja formation (*Mazapilites* beds), collections 12 and 15 in Cañon del Toboso section, Durango.

Genus SOLENOMORPHA Cockerell, 1903

SOLENOMORPHA? JURASSICA
Imlay, n. sp.
Plate 51, figures 1–3

Species represented only by the holotype, whose posterior end is defective. Shell fairly small for genus, greatly elongated,

equivalve, very inequilateral, lanceolate in form, valves closed. Thickest a little above midheight and slightly posterior to beaks. Umbones fairly small, scarcely elevated, directed forward, well separated, situated far forward. A rounded swelling passes posteriorly from the umbo toward posteroventral margin, separating a flattened dorsal slope from the gently convex sides. Anterodorsal margin short and concave; posterodorsal margin long, nearly straight, almost parallel to ventral margin but approaching it posteriorly; posterior margin defective; ventral margin long and gently convex; anterior margin short, narrowly rounded. Shell marked with fine concentric growth lines, which follow the contour of the valve and are most conspicuous posteriorly. Ligamental groove poorly preserved, but apparently long and narrow. Internal characters unknown.

Dimensions of holotype: measured length, 60+ mm. (probably 5 mm. longer); height, 18 mm.; thickness, 16 mm.

Remarks.—Species assigned to the genus *Solenomorpha* range from Devonian to Triassic, but none has hitherto been recorded from Upper Jurassic rocks. The Mexican specimen agrees with the essential generic characteristics of previously described species of *Solenomorpha*, except that it is much thicker and its anterior end is more narrowly rounded.

Type.—Holotype 15931, Museum of Paleontology, University of Michigan.

Occurrence.—La Casita formation, locality A-6 about 3½ miles south of Las Cuevas, Durango.

Genus LUCINA Bruguière, 1797
LUCINA CONCAVIUSCULA
Imlay, n. sp.
Plate 52, figures 7–11

The species is represented by two specimens. Shell fairly small, equivalve, inequilateral, subovate in outline, moderately convex. Beaks fairly prominent, approximate, curved inward and forward, situated slightly back of the midlength. Umbonal ridge broadly rounded, extending from the beak to the lower posterior extremity. Area posterodorsal to the umbonal ridge is weakly depressed. Dorsal margin concave in front of beak, arched behind beak. Anterior margin rounding abruptly into dorsal margin, rounding evenly below into the regularly rounded ventral margin. Posterior margin long and gently convex, meeting dorsal margin at a subobtuse angle. Surface marked by concentric, narrow, fairly close but irregularly spaced lamellae, which become more widely spaced away from the umbones. Interspaces flat, marked by fine growth lines. Lunule deeply impressed. Hinge and internal characters unknown.

Dimensions in mm. are as follows:

Specimen	Length	Height	Thickness of both valves
Holotype 19348.....	20.5	21.2	12.5
Paratype 19361.....	14.7	15.7	9

Remarks.—The species is characterized by its height; its fairly closely spaced ribbing, and its deep lunule. *Lucina potosina* Castillo and Aguilera (1895, pp. 6, 7, pl. 4, figs. 2, 3, 6; pl. 5, figs. 11–14) is a more elongate form and has wider-spaced concentric ribbing.

Type.—Holotype 19348, paratype 19361, Museum of Paleontology, University of Michigan.

Occurrence.—La Caja formation (*Idoceras* beds) Puerto Blanco near Mazapil, Zacatecas, and one mile south of Mina de San Francisco in the Sierra de la Ventura, Coahuila.

LUCINA POTOSINA Castillo and Aguilera
Plate 55, figure 7

Lucina potosina Castillo and Aguilera, *1895*, Com. Geol. Mex., Bol. 1, p. 6, pl. 4, figs. 2, 3, 6; pl. 5, figs. 11–14.
Lucina potosina Cragin, *1905*, U. S. Geol. Survey Bull. 266, p. 72, pl. 13, figs. 4, 5.

Remarks.—This species is fairly common in northern Mexico in beds with *Idoceras* and *Mazapilites*. The figured specimen illustrates well the sculpture of the species, although its posterodorsal margin is distorted and partially defective. In general the Mexican forms differ from the Texas forms described by Cragin by being more inflated and by having more centrally situated beaks.

Hypotype.—19359 Museum of Paleontology, University of Michigan.

Genus ARCTICA Schumacher, 1817
ARCTICA COTEROI (Castillo and Aguilera)
Plate 55, figures 9, 10

Ciprina coteroi Castillo and Aguilera, *1895*, Com. Geol. Mexico, Bol. 1, p. 8, pl. 5, figs. 4–10.

Remarks.—Eleven specimens of this species were obtained from the beds with *Idoceras* about one mile south of Mina de San Francisco in the Sierra de la Ventura, Coahuila. The figured specimen illustrates the sculpture and form. The beaks are situated in the anterior fourth of the shell, or are even terminal. The specimen figured by Cragin (1905, p. 77, pl. 13, figs. 11, 12) as "*Cyprina*" *coteroi* Castillo and Aguilera is incorrectly identified. Cragin's specimen is an internal mold, which can hardly be compared with the Mexican species of Castillo and Aguilera but which has more centrally situated beaks and an entirely different outline.

Hypotype.—21152, Museum of Paleontology, University of Michigan.

Genus EOCALLISTA Douvillé, 1921
EOCALLISTA? cf. E. CUNEOVATUS (Cragin)
Plate 55, figures 2–6

The species is represented by about 50 internal molds, of which a few bear fragments of shell.

Shell subelliptical in outline, longer than high, somewhat compressed. Beaks small, low, approximate, directed forward, situated about four-tenths the length of the shell from the anterior extremity. Posterodorsal margin long, nearly straight, gently inclined; anterodorsal margin concave, shorter and steeper than posterodorsal; posterior margin gently convex, extremity rather abruptly rounded; ventral margin broadly rounded; anterior margin rather narrowly rounded. Outline of shell varies on different individuals. Surface marked by numerous narrow, raised, irregularly spaced, concentric growth lines and by broad, low growth undulations. Lunule poorly defined.

Dimensions in mm. as follows:

Specimen	Length	Height	Thickness
17619	20.5	16.0	9.2
21143	16.5	12.5	8.0
21144	12.5	9.0	?
21145	16.0	13.0	?

Remarks.—The generic position of this species is uncertain due to lack of knowledge of its internal structures. Except for the presence of a small lunule, it greatly resembles *Corbicella*. *Tapes? cuneovatus* Cragin (1905, p. 79, pl. 13, fig. 13) may be identical.

Figured specimens.—17619, 21143–21145, Museum of Paleontology, University of Michigan.

Occurrence.—La Casita formation (*Mazapilites* beds), localities 43, 46, and 57, Sierra de Parras, Coahuila.

Genus PLEUROMYA Agassiz, 1843
PLEUROMYA? INCONSTANS Castillo and Aguilera
Plate 55, figure 1

Pleuromya inconstans Castillo and Aguilera, *1895*, Com. Geol. Mexico, Bol. 1, p. 10, pl. 5, figs. 15, 16, and pl. 6, figs. 1–4.
Pleuromya inconstans Cragin, *1905*, U. S. Geol. Survey Bull. 266, p. 82, pl. 17, figs. 1–5, pl. 18, figs. 1–3.

Remarks.—This highly variable species is fairly common in Mexico in both La Casita and La Gloria formations. Overlapping of the right hinge margin on the left, which is characteristic of *Pleuromya* rather than *Panope* has been noted by Castillo and Aguilera (1895, p. 11) and Cragin (1895, p. 83). The writer examined Cragin's specimens from Texas as well as many Mexican specimens and considers that the apparent overlap of the valves is due to distortion. The posterior gape of the valves suggests an assignment to *Panope* rather than *Pleuromya*, which accords with the conclusions of Gillet (1924, p. 143).

Hypotype.—21155, Museum of Paleontology, University of Michigan.

Occurrence.—In Mexico from localities A-6, A-13, A-19, and A-20 in the Villa Juarez uplift, eastern Durango; localities K-87 and K-92, Sierra de Jimulco, Coahuila.

Genus PHOLADOMYA Sowerby, 1825
PHOLADOMYA PAUCICOSTA Roemer? (Cragin)
Plate 54, figure 8

Pholadomya paucicosta? Cragin, *1905*, U. S. Geol. Survey Bull. 266, p. 81, pl. 16, figs. 5, 6.

Remarks.—This species is represented in the collections of the University of Michi-

gan by six specimens, which show considerable variation in dimensions. The most elongate specimen is figured and has the following dimensions: length, 62 mm., height, 57 mm., thickness of both valves, 33 mm.

Figured specimen.—21154, Museum of Paleontology, University of Michigan.

Occurrence.—In Mexico from La Casita formation at localities J-5 and A-13, Villa Juarez uplift, eastern Durango.

Genus CERCOMYA Agassiz, 1843

CERCOMYA DURANGENSIS Imlay, n. sp.

Plate 55, figures 11–13

The species is represented in the University of Michigan collections by seven somewhat compressed specimens, which show considerable variation in their relative dimensions.

Shell inequilateral, nearly equivalve, compressed, oblong, attenuated posteriorly, moderately to considerably elongate, gaping at posterior end. Umbones broad, rounded. Beaks small, low, approximate, inclined posteriorly, situated from two-fifths to three-fifths the length of the shell from the anterior extremity. Anterodorsal margin gently convex, slightly inclined; posterodorsal margin excavated behind umbones, then nearly straight to posterior extremity; anterior margin broadly rounded; posterior margin narrowly rounded; ventral margin long, gently convex, constricted near its midlength. Surface divided into two areas by a gentle, broad constriction, which passes from the lower part of the umbo backward to the ventral margin at a slight angle with the vertical. It appears to be more deeply impressed on the right valve than on the left. Ornamentation consists mainly of rounded concentric undulations, which are coarse and prominent on the anterior part of the shell but weak on the posterior part. Posterior part of shell marked in addition with about eight weak, narrow riblets, which begin high on the posterior side of the umbo and pass obliquely backward to the ventral margin. Riblets closely crowded on umbo, becoming widely separated at ventral margin.

Dimensions in mm. as follows:

	Length	Height	Thickness of both valves
Paratype 21141.....	72+	46	20+
Holotype 21140.....	100+	45	22+

Remarks.—The occurrence of radial riblets in *C. durangensis* Imlay is unique for the genus, although fine radial striae occupying a similar position on the shell occur in some species, e.g., *C. bipartita* (d'Orbigny) (Cottreau, 1929, p. 95, pl. 52, fig. 14). The other characteristics indicate that the generic determination is correct.

Remarks.—This species may be distinguished from *"Anatina" obliquiplicata* Cragin (1905, p. 85, pl. 16, figs. 7, 8) by its much larger and relatively narrower form and by its finer ribbing at a comparable size.

Type.—Holotype 21140, paratype 21141, Museum of Paleontology, University of Michigan.

Occurrence.—La Casita formation, locality A-13, Villa Juarez uplift, near Las Cuevas, Durango.

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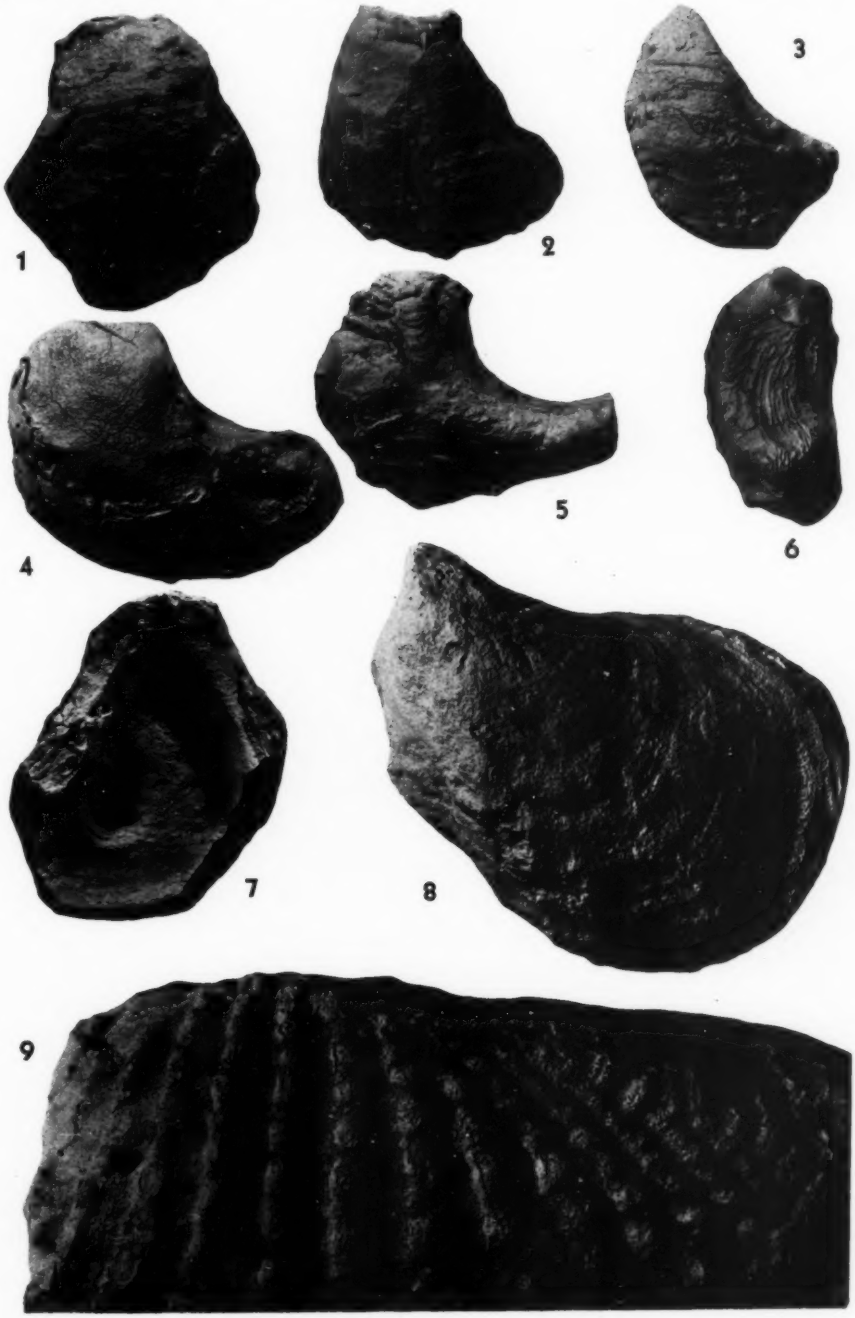
EXPLANATION OF PLATE 54

FIGS. *1–7*—*Gryphaea* cf. *G. mexicana* Felix. *1*, Left valve, U. M. 21147; *2*, left valve, U. M. 21146; *3*, *6*, lateral and posterior views of left valve, U. M. 21150; *4*, left valve, U. M. 21148; *5*, left valve, U. M. 21149; *7*, interior of left valve, U. M. 21151. All specimens from locality A-20, Villa Juarez uplift, eastern Durango. (p. 402)

8—*Pholadomya paucicosta* Roemer? U. M. 21154, locality A-13, Villa Juarez uplift, eastern Durango. (p. 409)

9—*Trigonia vyschetzkii* Cragin. Upper part of a large left valve, hypotype U. M. 21153, locality K-92, Sierra de Jimulco, Coahuila. (p. 402)

All figures natural size.



Imlay, Upper Jurassic Pelecypods

Imlay, Upper Jurassic Pelecypods

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MANUSCRIPT RECEIVED BY THE EDITOR NOVEMBER 6, 1939.

EXPLANATION OF PLATE 55

FIG. *1—Pleuromya? inconstans* Castillo and Aguilera. Typical elongate form, hypotype U. M. 21155, locality A-13, Villa Juarez uplift, eastern Durango. (p. 409)

2–6—Eocallista? cf. *E. cuneovatus* (Cragin). *2*, U. M. 21143, locality 46; *3*, U. M. 21144, locality 46; *4*, U. M. 21145, locality 46; *5*, *6*, U. M. 17619, locality 43. All specimens from the Sierra de Parras, Coahuila. (p. 409)

7—Lucina potosina Castillo and Aguilera. Hypotype U. M. 19359, Puerto Blanco, near Mazapil, Zacatecas. (p. 408)

8—Trigonia calderoni (Castillo and Aguilera). Hypotype U. M. 21142, locality A-6, Villa Juarez uplift, eastern Durango. (p. 402)

9–10—Arctica coteroi (Castillo and Aguilera). Lateral and dorsal views of hypotype U. M. 21152, Sierra de la Ventura, Coahuila. (p. 409)

11–13—Cercomya durangensis Imlay, n. sp. *11–12*, Paratype U. M. 21141; *13*, holotype U. M. 21140. Both specimens from locality A-13, Villa Juarez uplift, eastern Durango. (p. 410)

All figures natural size.

(*See opposite page 414 for Plate 56*)

EXPLANATION OF PLATE 56

FIGS. *1, 2—Trigonia munita* Cragin. Right valve and dorsal views of hypotype U. M. 21197, ×1 locality K-92, Sierra de Jimulco, Coahuila. (p. 402)

3–6—Nucula? antiqua Imlay, n. sp. Dorsal and lateral views of holotype U. M. 16970. Figures *3* and *4* are enlargements ×3 of *5* and *6* respectively, which are ×1. Locality 57, Sierra de Parras, Coahuila. (p. 400)

JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 5, PP. 412–416, PL. 57, SEPTEMBER, 1940

NEW LARGER FORAMINIFERA FROM THE CLAIBORNE OF MISSISSIPPI

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ABSTRACT—*Camerina barkeri*, *C. mississippiensis*, and *Lepidocyclina* (*Lepidocyclina*) *claibornensis* are described and figured as new species from the subsurface Cook Mountain formation (Claiborne Eocene) of George County, Miss. These species characterize a good zone for subsurface correlation from Louisiana to Florida.

IN A PAPER ON "Subsurface Tertiary zones of correlation through Mississippi, Alabama, and Florida" (Gravell and Hanna, 1938) we referred to a zone as "*Camerina* (large)." This zone occurs just above the *Lepidocyclina* (*Polylepidina*) zone, which is characterized by *L.* (*Polylepidina*) *gardnerae* Cole (1929, p. 4, pl. 1, figs. 1–6; pl. 2, figs. 1, 2) and below the top of the *Ceratobulimina eximia* zone, characterized by *Ceratobulimina eximia* (Rzehak) (1888, p. 263, pl. 11, figs. a–c). The later two zones are of Cook Mountain age, Claiborne Eocene. However, as noted in the paper, the top of the *Ceratobulimina eximia* zone is often difficult to determine in parts of Mississippi and Alabama because of the scarceness of *C. eximia*. Above the *C. eximia* zone is the *Camerina jacksonensis* zone of the Moody's Branch, Jackson Eocene, characterized by *Camerina jacksonensis* Gravell and Hanna (1935, p. 331, pl. 29, figs. 1–5, 7, 8, 10, 11, 13, 14). This is an excellent zone of correlation from Texas to Florida.

We wrote as follows:

Camerina (large) zone. This zone has been found to be of value in this part of the Claiborne section. At least two species of *Camerina* (pl. 5, figs. 11 and 13; pl. 6, figs. 2 and 5, pl. 7, figs. 5 and 6) are present, a smooth one and a beaded one. As far as the writers have been able to determine, neither species has been described, and rather than introduce a nude name they are referred to merely as large. They appear to be scarce or absent in western Mississippi. Eastward as the section becomes more marly or calcareous *Operculinoides* (large) [*Operculinoides* (large) should have been *Camerina* (large)] appear in abundance. In the harder limestones the surface may not break free from the matrix but some specimens break along the median plane and recognition is easy. In cuttings they can ordinarily be found by screening the coarser material from the finer. The interval from the top of the *Camerina jacksonensis* zone to the first appearance of *Camerina* (large) is commonly between 50 and 80 feet. This zone is not shown on the section since it is such a short distance below the *Camerina jacksonensis* zone (Gravell and Hanna, 1938, p. 1007).

The fossils described herein are from the Gulf Refining Company of Louisiana's Pascagoula Lumber Company No. 2, sec. 15, T. 3 S., R. 7 W., George County, Miss. They occur in a fairly well cored marly limestone, which allows for precise determination of their stratigraphic position. The following sequence of zones occurs in the well:

Camerina jacksonensis first observed in middle of core from 2238–50 feet.

Camerina barkeri Gravell and Hanna, n. sp., first observed in core from 2284–88 feet.

Lepidocyclina (*Lepidocyclina*) *claibornensis* Gravell and Hanna, n. sp., first observed in core from 2284–88 feet.

Camerina mississippiensis Gravell and Hanna, n. sp., first observed in top of core from 2340–44 feet.

Lepidocyclina (*Polylepidina*) *gardnerae*, first observed in core from 2350–53 feet.

Camerina barkeri and *Lepidcocyclina* (*Lepidocyclina*) *claibornensis* occur together but were not noted in this well with *Camerina mississippiensis*.

The syntypes of the species described in this paper will be deposited in the United States National Museum.

SYSTEMATIC DESCRIPTION

Family CAMERINIDAE

Genus CAMERINA Brugière, 1792

CAMERINA BARKERI Gravell and Hanna, n. sp.

Plate 57, figures 1–6

Camerina (large) GRAVELL and HANNA, *1938*, Am. Assoc. Petroleum Geologists, Bull., vol.

22, no. 8, p. 1007, pl. 5, figs. 11 and 13; pl. 6, figs 2 and 5; pl. 7, figs. 5 and 6.
Operculinoides (large) GRAVELL and HANNA. Idem, p. 1007.

Specimens of both microspheric and megalospheric forms present in nearly equal numbers. Test of both microspheric and megalospheric forms completely involute, thickly lenticular, with only a slight suggestion of a flange or keel. Sutures of clear shell material, smooth, distinct but not raised on surface of test (Our figured specimen, pl. 57, fig. 1, has most of the outer whorl broken off. The septa of the figure are of the preceding whorl and not raised sutures.) Sutures nearly straight to slightly curved, some of the sutures more or less irregular; that is, there may be several branching off from a single suture, in which they may be strongly curved (see pl. 57, fig. 2).

Our largest megalosopheric specimens show about 6½ whorls, which slowly increase in width; diameter, about 3.6 mm., thickness, about 2.5 mm. Number of chambers: first whorl 9; second, 15–16; third, 18–20; fourth, 22–24; fifth, 24–26; sixth, 28–29; inside diameter of initial chamber, 0.13 mm.

Our largest microspheric specimens show about 9 whorls, which slowly increase in width; diameter, about 5.3 mm.; thickness, about 2.5 mm. Number of chambers in last whorl, about 37.

Vertical sections show the shell walls to be very thick in both microspheric and megalospheric forms. The microspheric shell walls are by far the thicker. Vertical section also shows the test completely involute, with alar projections of the chambers extending over the center of the test uninterrupted by any cone of shell material.

The species is named in honor of R. Wright Barker, whose paleontologic work has been of great help to students of American larger Foraminifera.

Comparisons.—Camerina barkeri most closely resembles *C. mississippiensis* Gravell and Hanna, n. sp. *C. barkeri* lacks beads or nodes as surface ornamentation as contrasted with *C. mississippiensis*, being somewhat larger, slightly thinner, and having more whorls. *C. barkeri* differs from *C. petri* M. G. Rutten (1935, pp. 530–531, pl. 59, figs. 1–5; text fig. 2) and *C. striatoreticulata* (L. Rutten) (1928, pp. 1068–1069, figs. F–I), in having the initial chamber only about half as large. It differs from these also in being a considerably smaller species. *C. barkeri* differs from *C. petri* in lack of beads or nodes as surface ornamentation. Barker (1938) considered *C. petri* and *C. striatoreticulata* as identical. There is little similarity between *C. barkeri* and described species of American *Camerina* other than those mentioned.

Types.—Syntypes (the figured specimens) are from the top of a core from 2291–98 feet in the Gulf Refining Company of Louisiana's Pascagoula Lumber Company No. 2, sec, 15, T. 3 S., R. 7 W., George County, Miss.

Geologic horizon.—Cook Mountain, Claiborne Eocene, about 55 feet above the *Lepidocyclina* (*Polylepidina*) *gardnerae* Cole zone.

CAMERINA MISSISSIPPIENSIS
Gravell and Hanna, n. sp.
Plate 57, figures 7–11

Camerina (large). GRAVELL and HANNA, *1938*, Am. Assoc. Petroleum Geologists Bull., vol. 22, no. 8, p. 1007.
Operculinoides (large). GRAVELL and HANNA, *1938*, idem, p. 1007.

Specimens of both microspheric and megalospheric forms fairly abundant and in nearly equal numbers. Test of both microspheric and megalospheric forms completely involute, thickly lenticular, with only a very slight suggestion of a flange or keel. Sutures of clear shell material, not appreciably raised, with irregular thickenings forming nodes or beads, which are more prominent over the center of the test.

Sutures straight to only slightly irregularly wavy; some of the sutures more or less irregular, that is, there may be several branching off from a single suture.

Our largest megalospheric specimens show about 4½ to 5 whorls, which slowly increase in width; diameter up to about 3.5 mm.; and a thickness up to about 1.75 mm. Number of chambers: first whorl, 9; second, 15–16; third, 18–19; fourth, 21–22.

Our largest microspheric specimens show about 6 to 6½ whorls, which slowly increase in width; maximum diameter, about 4.0 mm.; maximum thickness, about 2.3 mm; number of chambers in last whorl, about 36.

Vertical section shows shell walls to be very thick in both forms. The microspheric shell walls are by far the thicker. Vertical sections show test to be completely involute, with alar projections of the chambers extending past the center.

Comparisons.—*Camerina mississippiensis* most closely resembles *C. barkeri* Gravell and Hanna n. sp. It differs from that species, however, in being noded or beaded, in being somewhat smaller, in having fewer whorls, and in being somewhat thicker. Like *C. barkeri*, it differs from *C. petri* M. G. Rutten and *C. striatoreticulata* (L. Rutten) in being of smaller size and having a smaller initial chamber.

Types.—Syntypes (the figured specimens) are from the top of a core from 2340–44 feet in the Gulf Refining Company of Louisiana's Pascagoula Lumber Company No. 2, sec. 15, T. 3 S., R. 7 W., George County, Miss.

Geologic horizon.—Cook Mountain, Claiborne Eocene immediately above the top of the *Lepidocyclina* (*Polylepidina*) *gardnerae* Cole zone.

Family ORBITOIDIDAE
Genus LEPIDOCYCLINA Gümbel, 1868

LEPIDOCYCLINA (LEPIDOCYCLINA) CLAIBORNENSIS Gravell and Hanna, n. sp.
Plate 57, figures 12–18

Both microspheric and megalospheric forms of this species were found.

Megalospheric form.—Test small, fairly thickly lenticular, not umbonate, diameter of adult specimens about 2.5 to 2.75 mm.; thickness decreasing gradually from the center to the periphery; test apparently without a peripheral flange; surface of test ornamented with prominent papillae, ranging in diameter from about 100 to 200μ, those over the center of the test being the larger, interspaces between papillae somewhat less than the diameter of the papillae.

Embryonic apparatus fairly thick walled, roughly ellipsoidal, composed of two equal to subequal chambers separated by a thin straight common wall; in two syntypes (pl. 57, figs. 15, 18) the greater diameters of the embryonic apparatus, including the chamber walls, being about 0.42 and 0.56 mm.; excluding walls, about 0.36 and 0.49 mm.; lesser diameter including walls about 0.31 mm., excluding walls about 0.26 mm. Height of embryonic apparatus from vertical section (pl. 57, fig. 18), including walls, about 0.38 mm.; excluding walls, about 0.32 mm. On each side of the embryonic apparatus (pl. 57, fig. 15) at the junction of the two large chambers is a chamber which is somewhat larger than the other chambers surrounding the embryonic apparatus, being about 130 to 170μ long and about 80μ wide.

The equatorial chambers in horizontal section (pl. 57, fig. 15) have flatly curved outer walls, inner walls formed by the converging ends of the chambers of the preceding annulus; in most chambers the tangential diameters are greater than the radial diameters. The chambers vary considerably in size but show little if any increase or decrease in the average size from near the embryonic apparatus to the periphery of the test, the larger and smaller chambers being interspersed throughout the equatorial layer, tangential diameters ranging from about 60 to 120μ, radial diameters from about 40 to 80μ, roofs and floors perforated by minute pores.

Vertical section (pl. 57, fig. 18) shows that the equatorial chambers vary little in height from the embryonic apparatus to the periphery of the test, being from about 80 to 90μ near the embryonic apparatus and about 100 to 120μ near the periphery.

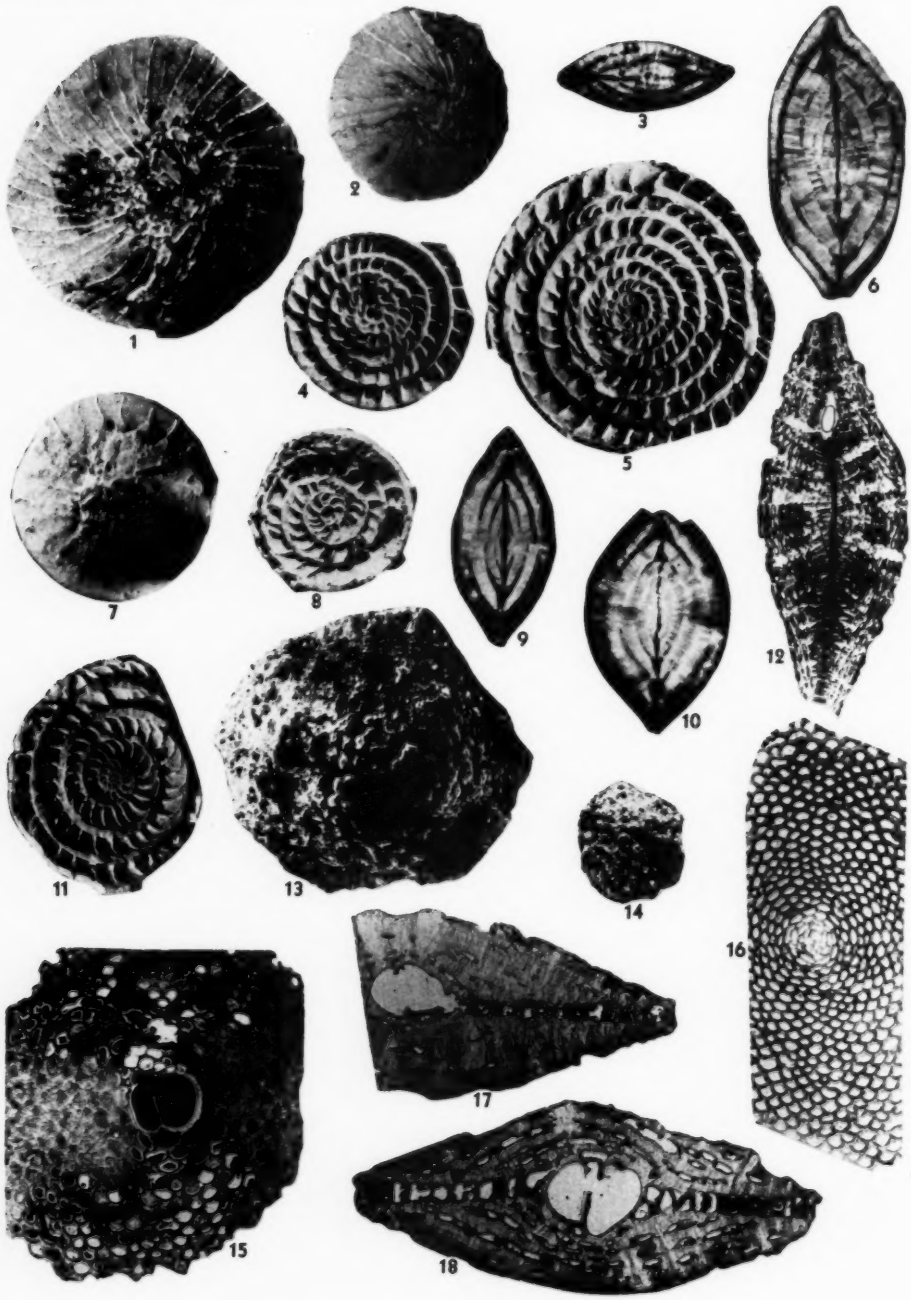
Lateral chambers consist of about 6 layers on each side of the equatorial zone (pl. 57, fig. 18) decreasing in number to none at the periphery; not arranged in definite regular tiers; chamber spaces roughly lenticular, thin compared with the roofs and floors, which are usually about twice as thick as the height of the chamber spaces. In some specimens (pl. 57, fig. 17) the lateral chambers are reduced almost to mere irregularly scattered slits.

The pillars are large, cone-shaped, increasing in diameter toward the surface, largest over the center of the test.

Microspheric form.—Similar to the megalospheric in the shape and ornamentation of the test, but its diameter and thickness are

(*For explanation of Plate 56, see bottom of page 411*)

Imlay, Upper Jurassic Pelecypods



Gravell and Hanna, Eocene Foraminifera

about three times those of the megalospheric form.

Microspheric specimens are abundant, having the same general shape as the megalospheric form, but are much larger. Syntype (pl. 57, fig. 13), which has its margins broken, has a diameter of about 6.0 mm. and a thickness of about 2.5 mm.; test covered with large papillae, which range from about 130 to 350μ in diameter, those on the central portion of the test being the larger.

The embryonic apparatus of the microspheric form (pl. 57, fig. 15) consists of about 1–1½ whorls of very small chambers, which are followed by the equatorial chambers. The equatorial chambers near the center of the test are roughly hexagonal; tangential diameters greater than the radial, about 60 to 80μ and 30 to 40μ respectively.

The equatorial chambers increase in size gradually from the center of the test to the periphery, the radial diameters increasing the more rapidly; with the relative increase of the radial diameters, the equatorial chambers become arcuate at a distance of about 0.4 mm. from the center of the test; at a distance of about 2.2 mm. from the center of the test the radial diameters are nearly equal to the transverse diameters, being about 100 to 110μ and 120 to 130μ respectively. A vertical section (pl. 57, fig. 12) shows the equatorial chamber spaces increasing in height gradually from about 40μ near the center to about 210μ at a distance of 3.0 mm. from the center.

Lateral chambers consist of about 20 layers over the center on each side of the equatorial layer in a specimen which has a thickness of about 2.5 mm., decreasing to none at the periphery of the test; chamber spaces roughly lenticular, near the center of the test they appear almost as mere slits, the roofs and floors being several times as thick as the height of the chamber spaces, toward the surface and the periphery the chamber spaces increase in height and length, attaining dimensions of from 40 to 60μ and 100 to 120μ respectively; the roofs and floors tending to decrease in thickness as the chamber spaces increase in length and height.

Pillars large; cone-shaped, increasing in diameter toward the surface; diameter from about 130 to 350μ, the larger being in the central part of the test.

Comparisons.—*Lepidocyclina* (*Lepidocyclina*) *claibornensis* Gravell and Hanna n. sp. differs from *L.* (*L.*) *ariana* Cole and Ponton (1934, pp. 142–143, pl. 2, figs. 1–5) in having a slightly greater diameter and being nearly twice as thick. There are about 6 layers of lateral chambers in *L.* (*L.*) *claibornensis* as contrasted with only 2 to 3 layers in *L.* (*L.*) *ariana*. The roofs and floors of the lateral chambers are considerably thicker in *L.* (*L.*) *claibornensis*. In some specimens of *L.* (*L.*) *claibornensis* many of the lateral chambers are very thin or lacking. The microspheric form of *L.* (*L.*) *ariana* is not known.

With the possible exception of *L.* (*L.*) *ariana*, which was described from well cuttings from 1340 feet below the top of the

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EXPLANATION OF PLATE 57

FIGS. *1–6*—*Camerina barkeri* Gravell and Hanna n. sp. *1*, Surface of microspheric form, outer whorl broken off; *2*, surface of megalospheric form, outer whorl broken off; *3*, vertical half section megalospheric form; *4*, horizontal half section megalospheric form; *5*, horizontal half section microspheric form. All ×8.75. From top of a core from 2291–98 feet. (p. 412)

7–11—*Camerina mississippiensis* Gravell and Hanna n. sp. *7*, surface view; *8*, horizontal half section of megalospheric form; *9*, vertical half section of megalospheric form; *10*, vertical half section of microspheric form; *11*, horizontal half section of microspheric form. All figures ×8.75. From the top of a core from 2340–44 feet. (p. 413)

12–14—*Lepidocyclina* (*Lepidocyclina*) *claibornensis* Gravell and Hanna n. sp. *12*, Vertical thin section of microspheric form; *13*, surface microspheric form; *14*, surface megalospheric form. All figures ×8.75. From top of core from 2291–98 feet. (p. 414)

15–18—*Lepidocyclina* (*Lepidocyclina*) *claibornensis* Gravell and Hanna n. sp. *15*, Horizontal thin section of megalospheric specimen; *16*, horizontal thin section of microspheric form; *17*, *18*, vertical thin sections of megalospheric forms. All ×26. From the top of a core from 2291–98 feet.

All specimens from the Gulf Refining Company of Louisiana's Pascagoula Lumber Company No. 2, sec. 15, T. 3 S., R. 7 W., George County, Mississippi. (p. 414)

Ocala (Upper Eocene), Jefferson County, Florida, in undifferentiated Eocene, *L.* (*L.*) *claibornensis* is apparently the only *Lepidocyclina* (*Lepidocyclina*) s.s. so far described from the Claiborne or its equivalent in America.

Types.—Syntypes (the figured specimens) are from the top of a core from 2291–98 feet in the Gulf Refining Company of Louisiana's Pascagoula Lumber Company No. 2, sec. 15, T. 3 S., R. 7 W., George County, Miss.

Geologic horizon.—Cook Mountain, Claiborne Eocene, about 55 feet above the *Lepidocyclina* (*Polylepidina*) *gardnerae* Cole zone.

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CONODONTS FROM THE DEVONIAN AND ASSOCIATED CLAYS OF MINNESOTA

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ABSTRACT—Conodonts occur in the shaly partings of the Cedar Valley limestone in southern Minnesota. Devonian conodonts also occur in the clays above the same limestone in the vicinity of Austin, Minnesota. These latter, however, are mingled with others of undoubted Ordovician origin, hence it seems certain that the fauna of this clay deposit has had a dual origin. A number of new species are described from these several horizons.

THE Devonian of Minnesota consists of a variable series of calcareous beds included in the Cedar Valley limestone and rests disconformably on the Upper Ordovician. The Devonian, or Cedar Valley limestone, is not extensively exposed within the state, and some of its beds are known chiefly from well samples or from outcrops a short distance farther south in Iowa. A generalized section for Howard County, Iowa, given by Calvin (1) shows the thickness to be 128 feet. It is probably about the same in Minnesota (2) but may be slightly less at places owing to pre-Cretaceous or preglacial weathering and erosion.

Outcrops of the Cedar Valley limestone occur in Fillmore and Mower counties, but it underlies the drift in some of the counties farther north and west. At LeRoy, Minnesota, the middle division (the *Stromatopora* beds of the Cedar Valley limestone, as designated in Iowa) crops out and is quarried to some extent. These beds consist chiefly of an exceedingly high grade white limestone with some layers of yellow to brown dolomitic limestone and thin beds or partings of shale. These shale partings have yielded a number of conodonts.

In the vicinity of Austin about 10 feet of pale-blue to light bluish-gray clay, part of which may be red, occur on top of the Cedar Valley limestone. This has been exposed in cuts, such as at the underpass in Austin or the clay pit at the old brick and tile plant, but it is also penetrated by the drilled wells that extend downward into bed rock. This clay or shale lies at the base of the drift or between the drift and the limestone and is the clay that has been called Cretaceous. N. H. Winchell found it to contain both angiosperm and gymnosperm leaves (3). During the present study no megascopic fossils were collected from it except a few corals that were found in the shales along Rose Creek, where they appear to be residual Devonian material. The clay samples from the Austin region have been thoroughly explored for microfossils, and nothing younger than Devonian has been found in them. The exposures of the clay shale at present are too unsatisfactory to discuss in detail, but the fact that they are overlain by drift and that the lower part of the clay seems to bear a residual relation to the bedrock below suggests that this deposit is preglacial in origin, although its upper part may be contaminated by drift material such as granite boulders (4). The microscopic fauna is limited to conodonts, most of which are characteristic Devonian genera, but the clay also contains such other genera as *Belodus*, *Oistodus*, *Paltodus*, *Dichognathus*, *Ozarkodina*, etc., not usually found in the Devonian. Moreover, some of the species appear to be identical with well-known Ordovician forms. It appears, therefore, that the clay contains a mixed Ordovician and Devonian microfauna, the Ordovician element at least being residual material brought in from the north and west. The Devonian element, if residual, need not have been carried very far, for the clay directly overlies rocks of Devonian age and may itself be, in part, of that age.

The conodont fauna from the Cedar Valley limestone outcrops of southeastern Minnesota and from the same clay in the Austin region, is figured and described herewith. Many of the species found in the clay occur also in the linestone, and their De-

vonian age is assured. The clay in which the mixed Ordovician and Devonian fauna occurs is probably Cretaceous in age, as is indicated by its plant fossils. The whole conodont assemblage here discussed consists of some 70 species, of which about 40 are more or less characteristic Devonian forms, others represent long-range genera having Devonian representatives, and still others are probably derived from nearby outcrops of Ordovician rocks.

SYSTEMATIC DESCRIPTIONS

Genus ACODINA Stauffer, n. gen.

Simple straight to distinctly curved bladelike forms with flattened, lenticular to subtriangular cross section. They vary in shape from nearly symmetrical lancelike units that are widest at the base to forms with greatest width in the blade slightly above the base, and from those curving laterally to those with a distinct oral curvature. A wide conical pit appears in the under side of the base.

This genus lacks the distinct keel of *Acodus*, the symmetry and grooving of *Acontiodus*, and the rounded cross section of those elongate forms usually referred to *Distacodus*. The genus includes those forms from the Olentangy shale described as *Acodus formosus*, *Acodus inopinatus*, and *Acodus zionensis*. It seems evident that the genus *Acodus* probably should be restricted to Ordovician, possibly to Ozarkian forms and not be required to include those without keels or furrows on their inner and outer faces. The general appearance and structure of these Devonian forms makes it seem desirable to choose a generic name close to that of Pander's term.

Genotype; *Acodina lanceolata* Stauffer, n. sp. (pl. 60, figs. 29, 30).

ACODINA CONCAVA Stauffer, n. sp.
Plate 60, figure 31

Dental unit consisting of a medium to slender cusp with pointed apex, straight sharp edges, concave outer surface and convex inner. The base is deeply excavated by a subconical pit.

Holotype.—B 5669; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

ACODINA COVINA Stauffer, n. sp.
Plate 60, figure 33

Dental unit consisting of an asymmetrical bladelike cusp with sharp point, sharp irregular edges, one side flat and the other a rounded angle. Base with deep, narrow pit and blade inclined to base at about 30°.

Holotype.—B 5671; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

ACODINA CURVATA Stauffer, n. sp.
Plate 60, figures 3, 14–16

Dental unit consisting of small sharp incurving cusp flattened on the outer surface but rounded on the inner, thus making the cross section plano-convex. Edges sharp and only slightly produced at the base, where the corners are abruptly cut off. Base with a deep conical pit.

Syntypes.—B 5642, B 5653–B 5655; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, Homestead well, 1½ miles SW. of Austin, Minnesota; also clay above the limestone, brick and tile plant, Austin, Minn.

ACODINA CUSPIDATA Stauffer, n. sp.
Plate 60, figures 21–25

Dental unit consisting of an elongate, slightly incurving, laterally compressed cusp with sharp cutting edges, sharp point, and only slightly expanded base. The anterior and posterior parts of the base are truncate and pierced on under side by a short distinctly conical pit.

Syntypes.—B 5660–B 5664; Geological Museum, University of Minnesota.

Horizon and Locality.—Clay above the limestone, brick and tile plant, Austin Minn.

ACODINA DELATA Stauffer, n. sp.
Plate 60, figure 7

Dental unit consisting of a small to medium, slender, elongate, sharp-pointed, nearly straight cusp, flattened on the outer side and rounded convex on the inner side. Base expanded to nearly three times width of cusp, semitriangular in cross section and tapering rapidly through first eighth of

length. A conical excavation or cavity centrally located penetrates the unit a short distance.

Holotype.—B 5646; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, Homestead well, 1½ miles SW. of Austin, Minn.

ACODINA LANCEOLATA Stauffer, n. sp.
Plate 60, figure 29, 30

Dental unit consisting of a spear-shaped point or cusp with sharp edges, which are broadly curved or rounding to the base. One face of cusp is flat and the other angular, so that the cross section is a triangle. Base with a deep pyramidal pit.

Holotype.—B 5668; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, Homestead well, 1½ miles SW. of Austin, Minn.

ACODINA LIRATA Stauffer, n. sp.
Plate 60, figures 18, 45

Dental unit consisting of a thin, broad tapering blade or cusp with sharp smooth edges, sharp point, a flat side, and a slightly convex opposite side. Base deeply penetrated by conical cavity.

Holotype.—B 5657; paratype, B 5683; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone in the brick and tile plant and at the underpass, Austin, Minn.

ACODINA URSA Stauffer n. sp.
Plate 60, figures 1, 2

Dental unit consisting of a small, sharp-pointed, laterally compressed cusp with sharp edges produced at base, lenticular cross section and a shallow, narrow basal excavation.

Holotype.—B 5641; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, Homestead well, 1½ miles SW. of Austin, Minn.

ACODINA VELVA Stauffer, n. sp.
Plate 60, figures 19, 32, 39, 46

Dental unit consisting of a symmetrical slender cusp or blade with rounded lenticular cross section, blunt edges diverging evenly to near base, where they reverse and begin to approach each other. Base smaller than greatest width of cusp and moderately penetrated by a conical pit.

Syntypes.—B 5658, B 5670, B 5677, B 5684; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

ACODINA ZIONENSIS Stauffer
Plate 60, figure 38

Acodus zionensis STAUFFER, *1938*, Jour. Paleontology, vol. 12, pp. 417, 418, pl. 49, fig. 30.

This specimen resembles very closely the one described from the Olentangy shale and doubtless should be included with it. The angles are slightly more rounded, and the position from which the drawing was made does not display the rapid curve of the sharp edge to the tip.

Figured specimen.—B 5676; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

Genus ANGULODUS Huddle, 1934

ANGULODUS ELONGATUS Stauffer, n. sp.
Plate 58, figures 1, 8, 21, 22

Bar rather thick, long, slightly compressed; anterior end curved laterally, deflected downward immediately in front of cusp and bearing short stout crowded denticles of rounded cross section, which are all of nearly the same size near the cusp but alternate with smaller ones farther anterior. Cusp small, about twice size of larger denticles and parallel with them. Posterior part of bar nearly straight but slightly twisted and bearing a double series of denticles, the larger increasing in size posteriorly, usually alternating with two to four of the smaller, and all inclined to posterior. Posterior extremity deflected downward, turned backward, laterally compressed and bearing a small number of subequal nearly horizontal denticles. Most of the denticles show insertion, and the larger suggest that they may have originated from multiple germ denticles. Under side of bar appearing sharp-edged, almost carinate, but inner margin slightly furrowed throughout length

of bar, and this furrow may be expanded into a slight pit beneath the cusp.

Holotype.—B 5525; paratypes, B 5532, B 5544; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone at the underpass and also in the brick and tile plant, Austin, Minn., and clay above the Cedar Valley limestone, Fowler and Pay quarry, Varco, Minn.

ANGULODUS sp.
Plate 58, figures 27, 30, 34

Several fragmentary specimens, probably belonging to two or three different species. Bar thick, becoming laterally compressed, deflected downward and slightly bowed though not recurved at posterior end. Under side may have a small pit beneath the cusp, succeeded by a broad furrow, which disappears and is replaced by a keel toward the posterior. Denticles laterally flattened, sharp-edged and sharp-pointed, discrete and consisting of a series of large individuals in the spaces between which there are one to four small denticles. Posterior denticles nearly horizontal, and downwardly deflected portion probably bearing four or more denticles.

Figured specimens.—B 5549, B 5552, B 5556; Geological Museum, University of Minnesota.

Horizontal and locality.—Clay above the limestone at the brick and tile plant, Austin and at Homestead well, 1½ miles SW. of Austin, Minn.; clay above the Cedar Valley limestone in the Fowler and Pay quarry, Varco, and upper part of Cedar Valley limestone, Hickok quarry, LeRoy, Minn.

Genus, BELODUS Pander, 1856
BELODUS DEVONICUS Stauffer, n. sp.
Plate 59, figures 47, 48

Base hollow, open at posterior, laterally compressed, bisymmetrical in cross section, sharply and deeply keeled on under side and upper side narrowing abruptly at a sharp angle into the dental ridge, anterior end curving upward into cusp, so that cusp is a direct continuation of bar. Dental edge bearing several dozen very slender denticles with edges fused throughout the greater part of their length.

Holotype.—B 5611; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

BELODUS TRIANGULARIS Stauffer, n. sp.
Plate 59, figure 49

Base or bar hollow, open at posterior, triangular in cross section; under side smooth, flat and meeting outer side in an approximate right angle. Inner edge sharply carinate and curving slightly upward. Anterior extremity of bar curved upward into cusp. Dental edge set with numerous small crowded erect denticles with edges fused, but free tips.

Holotype.—B 5612; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

Genus BRYANTODUS Ulrich and Bassler, 1926
BRYANTODUS BRICKERI Stauffer, n. sp.
Plate 58, figure 31

Base or bar slightly arched, thick, and in part made up of the fused bases of the denticles. One side, probably the inner, bears a distinct groove just below the denticles on the anterior limb, but the other side has a bulge or carina. A shallow pit or escutcheon occurs beneath the cusp, and from it narrow furrows are extended towards the extremities but are soon displaced by keels. Denticles thick, about uniform in size, closely packed, fused except at top and a half dozen or more on each limb. Those on the anterior limb not quite in a straight line. Cusp not much larger than adjacent denticles; extremities lacking.

Holotype.—B 5553; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

BRYANTODUS HICKOKI Stauffer, n. sp.
Plate 58, figure 18

Base relatively thin, regularly arched, both limbs slightly bowed inward. Escutcheon poorly developed, and faintly developed furrow on keeled under side of

limbs. The anterior limb bears at least six subequal denticles of rounded or circular cross section, discrete above point of eruption. The posterior limb with a similar number but of unequal size. Cusp inclined but straight and of moderate size. However, its base spreads out along the limbs of the bar to such an extent that several of the adjacent denticles may fail to erupt, and their germ bases may be included within that of the cusp.

Holotype.—B 5541; Geological Museum, University of Minnesota.

Horizon and locality.—Upper part of Cedar Valley limestone, Hickok quarry, LeRoy, Minn.

BRYANTODUS HORMELI Stauffer, n. sp.
Plate 58, figure 20

Base slightly arched, anterior limb deeper than posterior and slightly thicker. A fairly well developed pit or escutcheon with narrow furrows running out towards extremities. Both limbs appear to be keeled on under side except under high magnification. Anterior limb bearing about half a dozen closely placed nearly equal denticles but those of the posterior limb decreasing slightly towards the extremity. Cusp scarcely distinguishable from the denticles on either side.

Holotype.—B 5543; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

BRYANTODUS VERSUS Stauffer, n. sp.
Plate 59, figures 10, 14–16, 21

Bar very slightly arched, thin; beneath the cusp a deep pit elongate with direction of bar and becoming a groove. Posterior limb with eight or more similar denticles with edges fused. Anterior limb deeper and with a series of about six similar denticles. Cusp twice the size of adjacent denticles.

Syntypes.—B 5575, B 5579–B 5581, B 5586; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, Homestead well, 1½ miles SW. of Austin, Minn.; clay above the limestone at the underpass and at the brick and tile plant, Austin, Minn.; also clay above the Cedar Valley limestone, Fowler and Pay quarry, Varco, Minn., and upper part of Cedar Valley limestone, Hickok quarry, LeRoy, Minn.

BRYANTODUS sp.
Plate 58, figures 28, 32, 43; plate 59, figures 9, 11, 13, 22, 26, 28

A series of fragmentary specimens probably belonging to a half dozen or more species. Bar thick to thin, arched to nearly straight and slightly bowed; denticles laterally compressed, closely set, inserted, curving into near parallelism with base, and edges fused through part to more than half their length. On some fragments there may be 10 or more denticles on a limb. The germ denticles do not necessarily erupt or join with an adjacent denticle before eruption. Cusp variable, in some quite slender.

Figured specimens.—B 5550, B 5554, B 5565, B 5574, B 5576, B 5578, B 5587, B 5591, B 5593; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn., and upper part of Cedar Valley limestone, Hickok quarry, LeRoy, Minn.

Genus CERVICORNOIDES Stauffer, 1938

CERVICORNOIDES MINNESOTENSIS Stauffer, n. sp.
Plate 58, figure 23

Bar laterally compressed but fairly thick in middle part, flattened, slightly arched, and bowed at the posterior; a small, fairly deep pit with flaring inner margin occurs beneath the cusp, and the under side of posterior limb is keeled. Cusp of moderate size, set inward slightly out of line with denticles, and followed by a series of denticles of irregular size, the two or three immediately succeeding the cusp being smaller, but the fifth or sixth being much enlarged. The anterior limb is fragmentary on the specimen, but the dentition shows a series of varying size.

Holotype.—B 5545; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

CERVICORNOIDES sp.
Plate 58, figure 29; plate 59, figures 17, 27

Several specimens probably belonging to different species. The bar is thin, flattened, curled or bowed; under side grooved near center but slightly keeled towards the posterior. Denticles rounded in cross section to laterally compressed, sharp-edged, irregular in size, but generally a large one alternating with one to three small ones. In some the substance of base and denticles is somewhat transparent, and the development of the denticles may be seen to be as outgrowths of the base itself and with a structure like nested cones with base down. Other specimens show inserted cusp and denticles. The cones seem to start with their axes in a nearly horizontal position, then to push towards the extremity of the bar and gradually to turn upward into a nearly vertical position. Rarely (pl. 58, fig. 37) this same structure is shown in specimens that show suggestion of insertion of the denticles, thus making it less certain that these are actually different processes.

Figured specimens.—B 5551, B 5582, B 5592; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone at the brick and tile plant, Austin, and at the Homestead well, 1½ miles SW. of Austin, Minn.

Genus CTENOGNATHUS Pander, 1856
CTENOGNATHUS ELEGANS Stauffer
Plate 59, figures 3–5, 8

Ctenognathus elegans STAUFFER, *1938*, Jour. Paleontology, vol. 12, pp. 424, 425; pl. 48, figs. 9, 12.

Bar slightly arched and bowed, laterally compressed, keeled on under side except for slight pit beneath cusp. Anterior limb with 10 or a dozen closely set denticles with fused edges; posterior limb with seven or eight similar ones. The cusp is only slightly larger than the denticles. This species appears to be the same as that occurring in the Olentangy shale.

Figured specimens.—B 5568–B 5570, B 5573; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn., and clay above the Cedar Valley limestone, Fowler and Pay quarry, Varco, Minn.

Genus DICHOGNATHUS Branson and Mehl, 1933
DICHOGNATHUS POLITUS Stauffer, n. sp.
Plate 59, figures 43, 44, 54–56

Base with three limbs, two of which are nearly horizontal and meet at an angle approaching 90°, and the third of which extends sharply downward, nearly bisecting the 270° angle. Horizontal limbs bear a series of slender deeply set denticles that may show two sizes. Third or downward projecting limb bears six or eight relatively large denticles. Cusp long, slender, sharp-pointed and triangular in cross section, the corners of the triangle corresponding to the positions of the three bars forming the base.

Syntypes.—B 5608, B 5609, B 5617, B 5618; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone at the brick plant, Austin, Minn., and clay above the Cedar Valley limestone, Fowler and Pay quarry, Varco, Minn.

DICHOGNATHUS PROTEXUS Stauffer, n. sp.
Plate 59, figures 45, 46

Base with two prominent limbs forming an angle slightly greater than 90°, the third poorly developed. Under side deeply excavated beneath the cusp and along the limbs, decreasing in width towards the extremities. Denticulated edges of the two limbs with short fused denticles; the third slightly developed limb projecting downward as a short spur with only one or two denticles. Cusp short, stout, and triangular in cross section.

Holotype.—B 5610; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

Genus EUPRIONIODINA Ulrich and Bassler, 1926
EUPRIONIODINA sp.
Plate 58, figures 35, 37

Bar straight or very slightly arched,

thick, keeled on under side and tapering to posterior extremity. A dozen denticles of nearly same size preserved, curved slightly forward and inward, laterally compressed, closely crowded and fused throughout nearly half their length.

Figured specimens.—B 5557, B 5559; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the lime stone at the brick and tile plant, Austin, and clay above the Cedar Valley limestone at the Fowler and Pay quarry, Varco, Minn.

(*See opposite page 440 for Plate 60*)

EXPLANATION OF PLATE 60

FIGS. *1, 2—Acodina ursa* Stauffer, n. sp. Holotype, opposite side views, Homestead well, 1½ miles SW. of Austin, Minn., ×45. (p. 419)

3, 14–16—Acodina curvata Stauffer, n. sp. Syntypes. *3, 14, 15*, Brick and tile plant, Austin, Minn. *16*, Homestead well, 1½ miles SW. of Austin, Minn. All ×45. (p. 418)

4—Paltodus sp. Homestead well, 1½ miles SW. of Austin, Minn., ×30. (p. 428)

5, 12, 13, 17—Paltodus striatus Stauffer. Homestead well, 1½ miles SW. of Austin, Minn., ×30. (p. 428)

6—Paltodus belatus Stauffer, n. sp. Holotype, Homestead well, 1½ miles SW. of Austin, Minn., ×45. (p. 427)

7—Acodina delata Stauffer, n. sp. Holotype, Homestead well, 1½ miles SW. of Austin, Minn., ×45. (p. 418)

8, 9—Paltodus panderi Stauffer, n. sp. *8*, Holotype; *9*, paratype, brick and tile plant, Austin, Minn., ×30. (p. 427)

10—Paltodus cornutus Stauffer. Homestead well, 1½ miles SW. of Austin, Minn., ×45. (p. 427)

11—Paltodus subquadratus Stauffer, n. sp. Holotype, Homestead well, 1½ miles SW. of Austin, Minn., ×30. (p. 428)

18, 45—Acodina lirata Stauffer, n. sp. *18*, Holotype; *45*, paratype; brick and tile plant, Austin, Minn., ×45. (p. 419)

19, 32, 39, 46—Acodina velva Stauffer, n. Sp. Syntypes, brick and tile plant, Austin, Minn., ×45. (p. 419)

20—Oistodus abundans Branson and Mehl. Homestead well, 1½ miles SW. of Austin, Minn., ×30. (p. 426)

21–25—Acodina cuspidata Stauffer n. sp. Syntypes, brick and tile plant, Austin, Minn., ×45. (p. 418)

26–28, 34, 35, 41—Polygnathus juvensis Stauffer, n. sp. Syntypes, *26, 27, 34, 35, 41*, brick and tile plant, Austin, Minn.; *28*, Homestead well, 1½ miles SW. of Austin, Minn., ×30. (p. 429)

29, 30—Acodina lanceolata Stauffer, n. sp. Holotype, opposite side views, Homestead well, 1½ miles SW. of Austin, Minn., ×45. (p. 419)

31,—Acodina concava Stauffer, n. sp. Holotype, brick and tile plant, Austin, Minn., ×45. (p. 418)

33—Acodina covina Stauffer, n. sp. Holotype, brick and tile plant, Austin, Minn., ×45 (p. 418)

36, 43, 44, 52—Icriodus brevis Stauffer, n. sp. Syntypes, brick and tile plant, Austin, Minn., ×45. (p. 424)

37, 51, 56–58, 68—Icriodus cymbiformis Branson and Mehl. *37, 51, 56–58*, Homestead well, 1½ miles SW. of Austin, Minn.; *68*, brick and tile plant, Austin, Minn.; *56–58*, bottom, top and side views of one specimen; ×30. (p. 425)

38—Acodina zionensis Stauffer. Brick and tile plant, Austin, Minn., ×45. (p. 419)

40, 47, 48, 59–64, 70, 71—Icriodus expansus Branson and Mehl. *40, 59, 62–64, 70, 71*, Brick and tile plant, Austin, Minn.; *47, 48, 60*, Homestead well, 1½ miles SW. of Austin, Minn.; *61*, Fowler and Pay quarry, Varco, Minn.; *47, 48*, top and side views of one specimen; *62, 63*, top and bottom views of one specimen; *70, 71*, side and top views of one specimen; ×30. (p. 425)

42, 50, 54, 65–67, 69, 72–74, 78, 79—Polygnathus xylus Stauffer, n. sp. Syntypes. *42, 50, 54, 65, 66, 69, 72, 78, 79*, Brick and tile plant, Austin, Minn.; *67*, Hickok quarry, LeRoy, Minn.; *73*, Homestead well, 1½ miles SW. of Austin, Minn.; *78, 79*, side and bottom views of one specimen; *42, 50, 65, 67, 72, 78, 79* ×45, rest ×30. (p. 430)

49, 53, 55—Polygnathus varcus Stauffer, n. sp. Syntypes. *49*, Homestead well, 1½ miles SW. of Austin, Minn.; *53, 55*, Fowler and Pay quarry, Varco, Minn., ×30. (p. 430)

75–77—Polygnathus hulkus Stauffer, n. sp. Holotype, bottom, side and top views, Homestead well, 1½ miles SW. of Austin, Minn., ×30. (p. 429)

80, 82, 89, 90—Polygnathus sanduskiensis Stauffer. *80, 82*, Homestead well, 1½ miles SW. of Austin, Minn.; *89, 90*, brick and tile plant, Austin, Minn.; ×30. (p. 430)

81, 83–85—Polygnathus strongi Stauffer. *81*, Brick and tile plant, Austin, Minn.; *83–85*, Homestead well, 1½ miles SW. of Austin, Minn., ×30. (p. 430)

86–88—Polygnathus porcillus Stauffer, n. sp. Holotype, opposite sides and bottom views, underpass, Austin, Minn., ×30. (p. 430)

Genus HINDEODELLA Ulrich and Bassler, 1926

HINDEODELLA AUSTINENSIS Stauffer, n. sp.

Plate 58, figures 3–7, 9

Bar slightly compressed laterally, straight or slightly arched, with a long double series of one large alternating with one to five small sharp denticles. Cusp relatively large, straight and nearly parallel with other denticles. Anterior curled inward, extended downward much below level of bar, and bearing about a half dozen subequal denticles. A slight furrow on under side, which pinches out to anterior and posterior, but with small pit beneath cusp. Posterior portion may be keeled.

Syntypes.—B 5527, B 5528; paratypes, B 5529–B 5531, B 5533; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone at the brick and tile plant, Austin, and at the Homestead well, 1½ miles SW. of Austin, Minn.; also clay above the Cedar Valley limestone at the Fowler and Pay quarry, Varco, Minn., and upper part of the Cedar Valley limestone, Hickok quarry, LeRoy, Minn.

HINDEODELLA MOWERI Stauffer, n. sp.

Plate 58, figures 2, 10, 11

Bar thick, about as wide as deep, nearly straight, outer side less convex than inner, under side with a groove, which widens slightly on approaching the base of the cusp, under which it expands into a definite pit. Cusp relatively large, keeled, laterally flattened more on outer side, straight and directed to posterior at same angle as the denticles. Anterior limb bending abruptly downward, curving slightly inward, and bearing two large denticles, which alternate with sets of two small denticles. Posterior end is wanting on all specimens, but the fragments are sufficient to fix the genus and the species as different from others in the fauna. Numerous germ denticles arising deep within the bar erupt along the upper edge, forming a double but irregular series, in which individual larger denticles alternate with two to five or more of the small series.

Syntypes.—B 5526, B 5534, B 5535; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone at the underpass and the brick and tile plant, Austin, and at Homestead well, 1½ miles SW. of Austin, Minn.; also clay above the Cedar Valley limestone, Fowler and Pay quarry, Varco, Minn., and upper part of the Cedar Valley limestone, Hickok quarry, LeRoy, Minn.

HINDEODELLA sp.

Plate 58, figures 12–15, 19, 42

A number of large to small fragments probably belonging to several species. The bar is elongate, thick towards the anterior but becoming thin and deep towards the posterior, the whole curving slightly downward in the same direction. A double series of denticles, the larger increasing in size towards the posterior and alternating with denticles of the smaller series. Cusp and denticles inclined.

Figured specimens.—B 5536–B 5539, B 5542, B 5564; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone at the brick and tile plant, Austin, and at Homestead well, 1½ miles SW. of Austin, Minn.; also upper part of Cedar Valley limestone, Hickok quarry, LeRoy, and clay above the Cedar Valley limestone, Fowler and Pay quarry, Varco, Minn.

Genus ICRIODUS Branson and Mehl, 1938

ICRIODUS BREVIS Stauffer, n. sp.

Plate 60, figures 36, 43, 44, 52

Elongate dental plate with thin, rather deeply and broadly excavated base, which is nearly straight throughout. Oral surface with median row of a half dozen or more fairly sharp, partly fused denticles, the anterior of which is usually the largest. Lateral ridges with two to four sharp discrete denticles.

Syntypes.—B 5674, B 5681, B 5682, B 5689: Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone at the brick and tile plant and at the underpass, Austin, Minn.

ICRIODUS CYMBIFORMIS
Branson and Mehl
Plate 60, figure 37, 51, 56–58, 68

Icriodus cymbiformis BRANSON and MEHL, *1938*, Jour. Paleontology, vol. 12, p. 164, pl. 26, figs. 27–29.

Several specimens that appear identical with this species as collected from the Olentangy shale of Ohio. It has the same tapering base with wide flaring flange around deeper portion of basal cavity and the same denticulated central ridge carrying a dozen or more partly coalesced denticles with lateral ridges bearing three to five or six discrete ones.

Figured specimens.—B 5675, B 5688, B 5693, B 5702; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone at the brick and tile plant and at the underpass, Austin, and at Homestead well, 1½ miles SW. of Austin, Minn.

ICRIODUS EXPANSUS Branson and Mehl
Plate 60, figures 40, 47, 48, 59–64, 70, 71

Icriodus expansus BRANSON and MEHL, *1938*, Jour. of Paleontology, vol. 12, p. 160, pl. 26, figs. 18–21.

Wedge-shaped, elongate dental plates, some of which are slightly bowed. Base deeply excavated and with broad flaring rim around the anterior end. Median ridge with denticles crowded and coalescing or tied together by elevation of ridge itself. The lateral dental ridges bearing seven or eight medium to sharp denticles that may be tied across to opposite side through a median denticle. No prominent cusp.

Figured specimens.—B 5678, B 5685, B 5694–B 5698, B 5704; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone at the brick and tile plant and at the underpass, Austin, and at the Homestead well, 1½ miles SW. of Austin, Minn.; also in clay above Cedar Valley limestone, Fowler and Pay quarry, Varco Minn.

Genus LIGONODINA Ulrich and Bassler, 1926

LIGONODINA ARMENA Stauffer, n. sp.
Plate 59, figure 62, 63, 65, 71

Base with a slender posterior limb, grooved on under side and bearing a series of slender discrete denticles, which may begin close to cusp. The cusp is large, lies in plane of posterior limb, and is inclined with the denticles. The downward limb or anticusp is strongly developed, forms the anterior wall of the deep excavation, and bears about four strong discrete forward-curving denticles.

Syntypes.—B 5625, B 5627; paratypes, B 5624, B 5633; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, and at Homestead well, 1½ miles SW. of Austin, Minn.

LIGONODINA ATANA Stauffer, n. sp.
Plate 59, figure 73

Base with a slender posterior limb, grooved on under side, and with its dental edge bearing a series of small, slender, discrete denticles. The groove of base becomes deeper towards the anterior and passes into the cavity beneath the cusp. The anterior downward limb is bent much out of line with cusp and bears three or four, perhaps more, slender, discrete, very slightly curved denticles. Cusp robust, laterally flattened, and tapering to a point rather rapidiy.

Holotype.—B 5635; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

LIGONODINA FRANKLINENSIS Stauffer?
Plate 58, figure 24

Ligonodina franklinensis STAUFFER, *1938*, Jour. Paleontology, vol. 12, p. 431, pl. 51, figs. 5, 16.

Bar nearly straight or slightly arched at cusp. Conical pit beneath cusp. The posterior limb with wide shallow groove, and upper edge set with discrete, subequal denticles. Additional germ denticles show in the transparent base but do not appear to erupt. This may be the same as the Ohio species here indicated, but it is fragmentary and uncertain.

Figured specimen.—B 5546; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

LIGONODINA sp.
Plate 58, figures 33, 36, 40

Fragments of several species varying somewhat in detail. The bar or base is medium to wide, thin, or shallow to moderate in depth, tapering and with posterior slightly bowed; under side flat or nearly so, except for a slight ridge down the center. Denticles of the posterior part large, long, discrete, circular in cross section or slightly compressed, and all of about the same size except the last two or three, which may decrease in size rapidly. Some specimens show the internal structure through the translucent walls.

Figured specimens.—B 5555, B 5558, B 5562; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone at the brick and tile plant, Austin, and at Homestead well, 1½ miles SW. of Austin, Minn.

Genus LONCHODUS Pander, 1856
LONCHODUS sp.
Plate 58, figure 39

A fragmentary specimen consisting of a straight bar of nearly uniform width and thickness, grooved on under side and with upper bearing a series of similar, long, slender, discrete denticles. This specimen shows the internal structure and denticles apparently an integral part of the base or bar.

Specimens of this sort occurring at various horizons are referred to *Lonchodus* but it is more than probable that they are mere fragments of various other genera, such as *Subcordylodus*, *Ligonodina*, etc.

Figured specimen.—B 5561; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, Homestead well, 1½ miles SW. of Austin, Minn.

Genus METAPRIONIODUS Huddle, 1934
METAPRIONIODUS sp.
Plate 58, figure 26

Bar thick or heavy, slightly arched and twisted. Under side with a broad, shallow groove. Denticulated edge with alternating large and small laterally compressed discrete denticles. Both ends are broken and lost.

Figured specimen.—B 5548; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn., and upper part of Cedar Valley limestone, Hickok quarry, Le Roy, Minn.

Genus MICROCOELODUS Branson and Mehl, 1933
MICROCOELODUS sp.
Plate 59, figures 52, 68, 69

Several specimens showing cusps and fragments of the dental limbs of one or two species probably belonging to this genus. The cusp is long, slender, slightly curved, angular in cross section near base but nearly circular towards the apex. The limb preserved is broad, strong, curved down at extremity, nearly flat, with slight median furrow on under side and notch at base of cusp. Upper edge bears four strong denticles.

Figured specimens.—B 5615, B 5630, B 5631; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.; also clay above the Cedar Valley limestone, Fowler and Pay quarry, Varco, and upper part of Cedar Valley limestone, Hickok quarry, Le Roy, Minn.

Genus OISTODUS Pander, 1856
OISTODUS ABUNDANS Branson and Mehl
Plate 60, figure 20

Oistodus abundans BRANSON and MEHL, *1933*, Missouri, Univ. Studies, vol. 8, p. 109, pl. 9, figs. 11, 17.

A fragment, with others, showing the general characters of this species. It shows the laterally flattened, slightly bowed blade, making a low angle with the small base.

Figured specimen.—B 5659; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, Homestead well 1½ miles SW. of Austin, Minn.

Genus OZARKODINA Branson and Mehl, 1933
OZARKODINA CONCINNA Stauffer
Plate 59, figures 1, 2, 6, 7

Ozarkodina concinna STAUFFER, *1935*, Geol. Soc. America, Bull., vol. 46, p. 148, pl. 10, figs. 41, 45, 46.

Base or bar arched or consisting of two limbs meeting at an angle of about 140°, slightly bowed and flattened on inner side. Under side of base excavated throughout, being narrow at extremities but becoming wider and deeper at the angle or union of the two limbs, where the thin boundary edges may flare slightly outward. Cusp and denticles laterally compressed, short, sharp-edged and sharp-pointed. There are about five to seven denticles on the anterior limb, and three, four or five on the posterior limb. The cusp, about twice the length of denticles, occupying the apex of the angle and about parallel with denticles of posterior limb.

This species is probably *Ozarkodina concinna* from the Glenwood beds and Decorah shale, for some of the conodonts from this clay may have been derived from Ordovician rocks that crop out a short distance to the north. This genus was not found in the Devonian shales of the Lake Erie district (4) nor in the New Albany shale of Indiana (5), although several species have been described from the lower Mississippian of Missouri (6). From the above it seems possible that the genus may occur in the Devonian, but it is a common Ordovician form.

Figured specimens.—B 5566, B 5567, B 5571, B 5572; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

OZARKODINA CONGESTA Stauffer, n. sp.
Plate 59, figure 12

Base moderately arched, thinning towards extremities. Under side widely excavated, with shallow but wide pit beneath cusp. Anterior limb with a half dozen similar laterally compressed denticles, fused at base. Posterior limb not so deep and bearing about the same number of similar denticles. Cusp relatively small and nearly at right angles to posterior limb.

Hololype.—B 5577; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn., and upper part Cedar Valley limestone, Hickok quarry, LeRoy, Minn.

Genus PALTODUS Pandor, 1856

PALTODUS BELATUS Stauffer, n. sp.
Plate 60, figure 6

Dental unit consisting of a short, rapidly tapering, markedly curved cusp, only slightly flattened, with both upper and lower carinae sharp in midlength. Pronounced furrows on concave side, with a ridge or carina on inside or concave curvature. Outer curve thick and rounded. Base with a deep conical excavation.

Holotype.—B 5645; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, Homestead well, 1½ miles SW. of Austin, Minn.

PALTODUS CORNUTUS Stauffer
Plate 60, figure 10

Paltodus cornutus STAUFFER, *1935*, Jour. Paleontology, vol. 9, p. 612, pl. 74, figs. 1, 2, 11, 13–15, 19.

One of several fragments occurring in the clays that probably belong to this species.

Figured specimen.—B 5649; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, Homestead well, 1½ miles SW. of Austin, Minn.

PALTODUS PANDERI Stauffer, n. sp.
Plate 60, figures 8, 9

Dental unit consisting of strongly curved, slightly bowed bladelike cusp, which tapers gradually to a point, is flattened to slightly convex on inner side, and moderately to strongly convex on outer side. These two sides are separated by the sharp edges, which have flattened to furrowlike areas adjacent to them on inner side. Base slightly expanded laterally and greatly extended on inner side, compressed in the inner third. Excavation may be divided at the compressed region, the anterior conical cavity thus formed extending less than a third the length and the similar posterior cavity two-thirds the length of cusp.

Holotype.—B 5647; paratype, B 5648; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

PALTODUS STRIATUS Stauffer
Plate 60, figures 5, 12, 13, 17

Paltodus striatus STAUFFER, *1935*, Jour. Paleontology, vol. 9, p. 613, pl. 74, figs. 3, 16.

Dental unit consisting of long, slender, curving conelike cusp, thick at the base, with deep conical hollow or basal excavation and sharp point at apex. Although the cross section approaches circularity near the apical end, in midlength the concave side bears a finely grooved carinate fold that increases in height to the base and is bounded on either side by broad shallow furrows. Although these forms vary slightly from the types, they show striation and many of the characteristics of the species.

Figured specimens.—B 5644, B 5651, B 5652, B 5656; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone at the brick and tile plant, Austin, and at Homestead well, 1½ miles SW. of Austin, Minn.

PALTODUS SUBQUADRATUS Stauffer, n. sp.
Plate 60, figure 11

Dental unit consisting of an elongate slender cusp, which is nearly straight at base but curves inward along the upper part. Outer edge of cusp rounded, inner edge sharply carinate; lateral edges also carinate. Cross section subquadrate to nearly square, the angles being the carinae. Base small, not expanded, and with deep cavity extending half the length of the unit or more.

Holotype.—B 5650; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, Homestead well, 1½ miles SW. of Austin. Minn.

PALTODUS sp.
Plate 60, figure 4

Fragment of a medium to large form laterally compressed with carinate inner edge, rounded outer edge and furrows on either side. The hollow of base extends far up into the bladelike cusp.

Figured specimen.—B 5643; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, Homestead well, 1½ miles SW. of Austin, Minn.

Genus PANDORINA Stauffer, n. gen.

Dental units having a short bar, straight or slightly bowed, with a broad or rounded notch on under side posterior to the base of the cusp. Extremities of the bar not clearly marked but turning upward and rounding with added denticles. Cusp near the anterior, not always very pronounced, and commonly double. Denticles deeply set, laterally compressed, and fused nearly to the tips.

Genotype, *Pandorina insita* Stauffer, n. sp. (pl. 59, figs. 23, 25).

PANDORINA BRAMBONA Stauffer, n. sp.
Plate 59, figures 34–36

Bar moderately long, tapering to posterior; notch in base partly excavated and passing into a slight groove to posterior. Anterior of notch open with rapidly narrowing groove passing forward beneath cusp. Dental margin of posterior limb with 10 or more denticles of irregular size and with fused edges; usually those nearest the cusp are smaller. Anterior limb short, smooth, and a part of cusp or bearing one or two poorly developed denticles. Cusp rather large, laterally compressed, and may be crowded against nearest posterior denticles.

Holotype.—B 5600; paratypes, B 5599, B 5601; Geological Museum, University of Minnesota.

Horizon and locality.—Upper part of Cedar Valley limestone, Hickok quarry, LeRoy, Minn.

PANDORINA GRATIOSA Stauffer, n. sp.
Plate 59, figures 18–20, 24

Bar short, with broad rounded notch at center, the cusp base starting just off the anterior end of notch. Extremities of the bar thin and passing into denticulated margin by gradually rounding upward. Posterior limb with 10 or a dozen laterally compressed denticles, fused throughout except for tips. Anterior limb short and bearing one or two denticles. Cusp large, usually double, and may rise but little above the adjacent denticles.

Syntypes.—B 5583–B 5585, B 5589; Geological Museum, University of Minnesota.

Horizon and locality.—Upper part of Cedar Valley limestone, Hickok quarry, LeRoy, Minn.

PANDORINA INSITA Stauffer, n. sp.
Plate 59, figures 23, 25

Bar short, slightly bowed, and with a deep rounded notch near the center of the under side of base. Extremities subangular and thin. Posterior limb with about a dozen similar, laterally compressed denticles, fused with only the tips free. Anterior limb with three or four similarly compressed and fused denticles, of which the one nearest the cusp is largest, the others decreasing rapidly in size to the anterior end. Cusp relatively small and may be buttressed on inner side by a ridge or carina.

Syntypes.—B 5588, B 5590; Geological Museum, University of Minnesota.

Horizon and locality.—Upper part of Cedar Valley limestone, Hickok quarry, LeRoy, Minn.

PANDORINA sp.
Plate 58, figure 38

Base thin, not much expanded, with pit present but notch poorly developed, bowed at the cusp, which latter is wide and with edges fused with adjacent denticles. The anterior is broken but was probably shorter than average for the genus.

Figured specimen.—B 5560; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

Genus PLECTODINA Stauffer, 1935
PLECTODINA TILBARA Stauffer, n. sp.
Plate 59, figures 50, 57, 58, 64

Bar straight, thin, shallow, slightly bowed at anterior end, under side with groove passing forward into deep, narrow pit beneath cusp. Dental edge with half a dozen or more similar, closely set, erect, laterally compressed denticles. Cusp elongate, sharp-pointed, laterally compressed, with sharp edges making an angle of nearly 90° with the dental edge. Downward projection of cusp, or the anticusp, forming anterior boundary of the pit, with sharp smooth outer edge, and lower portion bowed inward.

Syntypes.—B 5613, B 5619, B 5620, B 5626; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

Genus POLYGNATHUS Ulrich and Bassler, 1926
POLYGNATHUS ANGULOSUS Stauffer, n. sp.
Plate 58, figure 41

Bar thick, massive, with pronounced flexure or bend. Anterior part expanded, posterior tapering from angle to a blunt point at extremity. Under side rounded and bearing a low keel, which passes into and through the shallow pit beneath the cusp. Posterior limb bearing half a dozen discrete short, stout denticles posterior to bend and three partly confluent ones in front or between bend and cusp. The cusp is short, stout, and erect. That part of the bar forming the anterior probably carries about three or four denticles and tapers forward.

Holotype.—B 5563; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

POLYGNATHUS HULKUS Stauffer, n. sp.
Plate 60, figures 75–77

Small unit, with base slightly bowed, under edge forming a sigmoid curve, and a relatively large flattened pit or attachment scar. Plate relatively short, with deep trough with smooth sides. The blade is slender, deep, and bears 8 or 10 closely set, laterally compressed, confluent denticles in front of the plate, over which it passes as a nodose median ridge.

Holotype.—B 5708; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, Homestead well, 1½ miles SW. of Austin, Minn.

POLYGNATHUS JUVENSIS Stauffer, n. sp.
Plate 60, figures 26–28, 34, 35, 41

Plate or dental unit elongate, nearly straight on upper edge, under side somewhat arched and slightly expanded with an attachment scar or pit at midlength. Blade thin and bearing a series of 12 to 20 closely set, laterally compressed denticles with partly fused edges. Some of the denticles small and appear to have been inserted between others to fill gaps. Plate almost obsolete, appearing as a pair of shelf-like ridges on the sides of the blade near pos-

terior end, either smooth or bearing three or four low tubercles or transverse ridges.

Syntypes.—B 5665, B 5566, B 5667, B 5672, B 5673; B 5679; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone at the brick and tile plant, Austin, and at Homestead well, 1½ miles SW. of Austin, Minn.

POLYGNATHUS PORCILLUS Stauffer, n. sp.
Plate 60, figures 86–88

Plate strongly arched and tapering posteriorly to a point. Under side keeled, with well developed median pit. Blade broken but probably short and bearing very few medium to large denticles on free end; extending back as a median ridge over the plate where the denticles are small, distant and approaching obsolescense. Five denticles are preserved on plate and one on free part of blade. Margins of plate scalloped as if the edges of once functional ridges.

Holotype.—B 5716; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, underpass, Austin, Minn.

POLYGNATHUS SANDUSKIENSIS Stauffer
Plate 60, figures 80, 82, 89, 90

Polygnathus sanduskiensis STAUFFER, *1938*, Jour. Paleontology, vol. 12, p. 438, pl. 53, figs. 27, 36, 37.

These specimens are indistinguishable from those found in the Olentangy shale of the Sandusky region of Ohio. These dental units are highly arched, especially in the posterior part and slightly bowed. The plate varies in depth and steepness of sides, and the outer rows of denticles are confluent with its edges. The blades are mostly gone, but fragments seem to show general characters of the species.

Figured specimens.—B 5710, B 5712, B 5717, B 5718; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone at the brick and tile plant, Austin, and at Homestead well, 1½ miles SW. of Austin, Minn.

POLYGNATHUS STRONGI Stauffer
Plate 60, figures 81, 83–85

Polygnathus strongi STAUFFER, *1938*, Jour. Paleontology, vol. 12, pp. 438–439, pl. 53, fig. 19.

These specimens vary somewhat, but they show the main characteristics of this species. Thus they show the plate to be flattened and covered with rows of nodes, the margins to be denticulate towards the front, and the median ridge formed by the portion of the blade traversing the plate and tending to be smooth or nodose.

Figured specimens.—B 5711, B 5713, B 5714, B 5715; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone at the brick and tile plant, Austin, and at the Homestead well, 1½ miles SW. of Austin, Minn.

POLYGNATHUS VARCUS Stauffer, n. sp.
Plate 60, figures 49, 53, 55

Plate short, straight or very slightly bent downward at posterior, and very gently bowed. Under side expanded and with broad, shallow pit at front of plate. Blade long, thin, and forming the median dental ridge with two dozen or more laterally compressed, sharp-edged denticles, which may partly coalesce at posterior, and whose sharp edges may fuse, or else small denticles may erupt between to fill the intervening space. Lateral dental ridges of plate smooth or slightly crenulate and extending a third to barely a half of the full length of the unit.

Syntypes.—B 5686, B 5690, B 5692; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above Cedar Valley limestone, Fowler and Pay quarry, Varco, Minn., and clay above the limestone, Homestead well, 1½ miles SW. of Austin, Minn.

POLYGNATHUS XYLUS Stauffer, n. sp.
Plate 60, figures 42, 50, 54, 65–67, 69, 72–74, 78, 79

Plate medium to long, straight to slightly arched, curving downward especially at the posterior, and may be bowed. Blade medium to long, constituting half or more of full length of unit and bearing on its upper edge about 20 laterally compressed denticles with confluent edges. The denticles forming the median ridge of the plate may coalesce into a nearly smooth ridge, which shows only a few nodes or little sign of den-

ticles. Lateral margins not ridgelike, but smooth or bearing a few obsolete nodes.

Syntypes.—B 5680, B 5687, B 5691, B 5699, B 5700, B 5701, B 5703, B 5705, B 5706, B 5707, B 5709; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone at the brick and tile plant and the underpass, Austin, and at the Homestead well, 1½ miles SW. of Austin, Minn.; also clay above the Cedar Valley limestone Fowler and Pay quarry, Varco, and upper part Cedar Valley limestone, Hickok quarry LeRoy, Minn.

Genus PRIONIODELLA Ulrich and Bassler, 1926
PRIONIODELLA MULATA Stauffer, n. sp.
Plate 58, figure 25

Bar laterally compressed, of moderate depth, broadly arched, and very slightly bowed inward. Shallow pit beneath the cusp with grooves extending from it towards both extremities but soon displaced by a keel. Cusp a little deeper but very slightly set off from the denticles, and all of similar size, closely crowded and with edges fused near the cusp but tending to become discrete near the anterior extremity. The anterior limb bears about 14 denticles. Posterior limb probably shorter; the fragment remaining has four.

Holotype.—B 5547; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

Genus PRIONIODINA Ulrich and Bassler, 1926
PRIONIODINA TORTUS Stauffer, n. sp.
Plate 58, figures 16, 17

Base elongate, thick, deep, with a broad shallow diamond-shaped pit beneath the cusp, and shallow furrow extending to both extremities. Anterior limb straight and massive, carrying a crowded series of similar laterally compressed denticles with edges fused in lower half. Posterior limb tortuous or twisted and carrying an irregular series of seven or eight laterally compressed, nearly discrete denticles. Cusp similar to denticles but about twice as large.

Holotype.—B 5540; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

Genus PRIONIODUS Pander, 1856
PRIONIODUS REMUS Stauffer, n. sp.
Plate 59, figures 29, 37, 51, 53, 66

Bar straight, rather thin, under side very slightly grooved, with notch beneath the cusp protected on inner side by a flange or lip. Dental edge of bar bearing an irregular series of closely set, slender, discrete, slightly incurving denticles. Cusp strongly developed, bladelike, with sharp edges almost or quite in line with denticles. Downward projection of base or anticusp nearly half as long as cusp itself and nearly at right angles to bar, with its outer margin a sharp cutting edge, but the inner margin flattened or slightly grooved. The dental units referred to this species vary slightly, but all seem to fall within the possibilities of a single form.

Syntypes.—B 5594, B 5602, B 5614, B 5616, B 5628; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone at the brick and tile plant and at the underpass, Austin, and at Homestead well, 1½ miles SW. of Austin, Minn.; also upper part of Cedar Valley limestone, Hickok quarry, LeRoy, Minn.

PRIONIODUS TARITUS Stauffer, n. sp.
Plate 59, figure 30

Bar slender, straight, notch beneath cusp rather deep and wide. Dental edge of bar bearing a series of similar denticles, which are discrete and not crowded. Cusp long, slender, and bent abruptly in at base. Downward projection rather short, spurlike, and making an angle of nearly 120° with the bar. Both bar and spur grooved.

Holotype.—B 5595; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

PRIONIODUS sp.
Plate 59, figure 42

Bar straight, thin, slightly grooved on under side, with well developed cavity or pit

beneath cusp. Dental edge of bar with a series of similar denticles with fused edges. Cusp relatively large, flattened, curved slightly inward and nearly parallel with denticles. Anticusp smooth.

Figured specimen.—B 5607; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

Genus SUBCORDYLODUS Stauffer, 1935
SUBCORDYLODUS sp.
Plate 59, figure 72

Bar straight, thin, grooved on under side, and bearing a series of discrete denticles on upper side. Cusp terminal, curved at base and becoming parallel to denticles. Under side of cusp with fairly deep pit.

Figured specimen.—B 5634; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

Genus SYNPRIONIODINA Ulrich and Bassler, 1926
SYNPRIONIODINA FORSENTA Stauffer, n. sp.
Plate 59, figures 31–33, 38–41

Bar straight or very slightly arched, gently bowed, slender and of nearly same depth throughout. Under side of bar finely grooved through greater part of length, and

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EXPLANATION OF PLATE 58

FIGS. *1, 8, 21, 22—Angulodus elongatus* Stauffer, n. sp., ×30. *1*, Holotype. *8, 21, 22*, Paratypes. Brick and tile plant, Austin, Minn. *21, 22*, Opposite side views of one specimen. (p. 419)

2, 10, 11—Hindeodella moweri Stauffer, n. sp. Syntypes, ×30. *2*, Homestead well, 1½ miles SW. of Austin, Minn.; *10*, underpass, Austin, Minn.; *11*, brick and tile plant, Austin, Minn. (p. 424)

3–7, 9—Hindeodella austinensis Stauffer, n. sp. *3, 4*, Syntypes, Fowler and Pay Quarry, Varco Minn. *5, 6*, Paratypes, brick and tile plant, Austin, Minn. *7, 9*, Paratypes, Homestead well, 1½ miles SW. of Austin, Minn. All ×30 except *7*, ×45. (p. 424)

12—Hindeodella sp. Homestead well, 1½ miles SW. of Austin, Minn., ×30. (p. 424)

13, 19—Hindeodella sp., Hickok quarry, LeRoy, Minn.; *13*, ×45; *19*, ×30. (p. 424)

14—Hindeodella sp., Fowler and Pay quarry, Varco, Minn., ×30. (p. 424)

15—Hindeodella sp., Hickok quarry, LeRoy, Minn., ×30. (p. 424)

16, 17—Prioniodina tortus Stauffer, n. sp. Holotype, opposite side views, brick and tile plant, Austin, Minn., ×30. (p. 431)

18—Bryantodus hickoki Stauffer, n. sp. Holotype, Hickok quarry, LeRoy, Minn., ×30. (p. 420)

20—Bryantodus hormeli Stauffer, n. sp. Holotype, brick and tile plant, Austin, Minn., ×30. (p. 420)

23—Cervicornoides minnesotensis Stauffer, n. sp. Holotype, brick and tile plant, Austin, Minn., ×30. (p. 421)

24—Ligonodina franklinensis? Stauffer. Brick and tile plant, Austin, Minn., ×30. (p. 425)

25—Prioniodella mulata Stauffer, n. sp. Holotype, brick and tile plant, Austin, Minn., ×30. (p. 431)

26—Metaprioniodus sp. Brick and tile plant, Austin, Minn., ×30. (p. 426)

27—Angulodus sp. Brick and tile plant, Austin, Minn., ×30. (p. 420)

28—Bryantodus? sp. Hickok quarry, LeRoy, Minn., ×30. (p. 421)

29—Cervicornoides sp. Homestead well, 1½ miles SW. of Austin, Minn., ×45. (p. 422)

30—Angulodus? sp. Brick and tile plant, Austin Minn., ×30. (p. 420)

31—Bryantodus brickeri Stauffer, n. sp. Holotype, brick and tile Plant, Austin, Minn., ×30. (p. 420)

32—Bryantodus sp. Hickok quarry, LeRoy, Minn., ×30. (p. 421)

33—Ligonodina sp. Brick and tile plant, Austin, Minn., ×30. (p. 426)

34—Angulodus sp. Homestead well, 1½ miles SW. of Austin, Minn., ×30. (p. 420)

35—Euprioniodina sp. Fowler and Pay quarry, Varco, Minn., ×30. (p. 422)

36—Ligonodina sp. Homestead well, 1½ miles SW. of Austin, Minn., ×30 (p. 426)

37—Euprioniodina sp. Brick and tile plant, Austin, Minn., ×30. (p. 422)

38—Pandorina sp. Brick and tile plant, Austin, Minn., ×30. (p. 429)

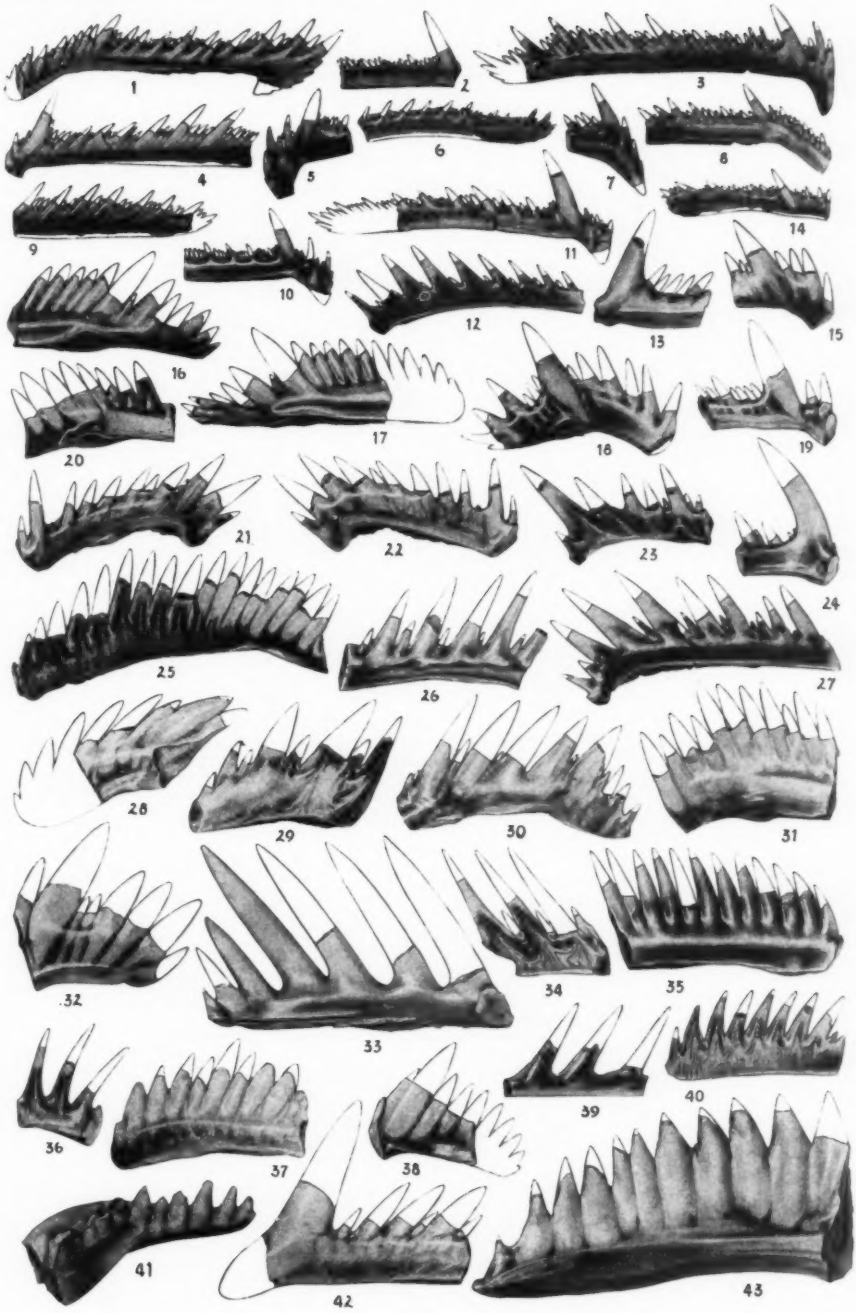
39—Lonchodus sp. Homestead well, 1½ miles SW. of Austin, Minn., ×30. (p. 426)

40—Ligonodina sp. Brick and tile plant, Austin, Minn., ×30. (p. 426)

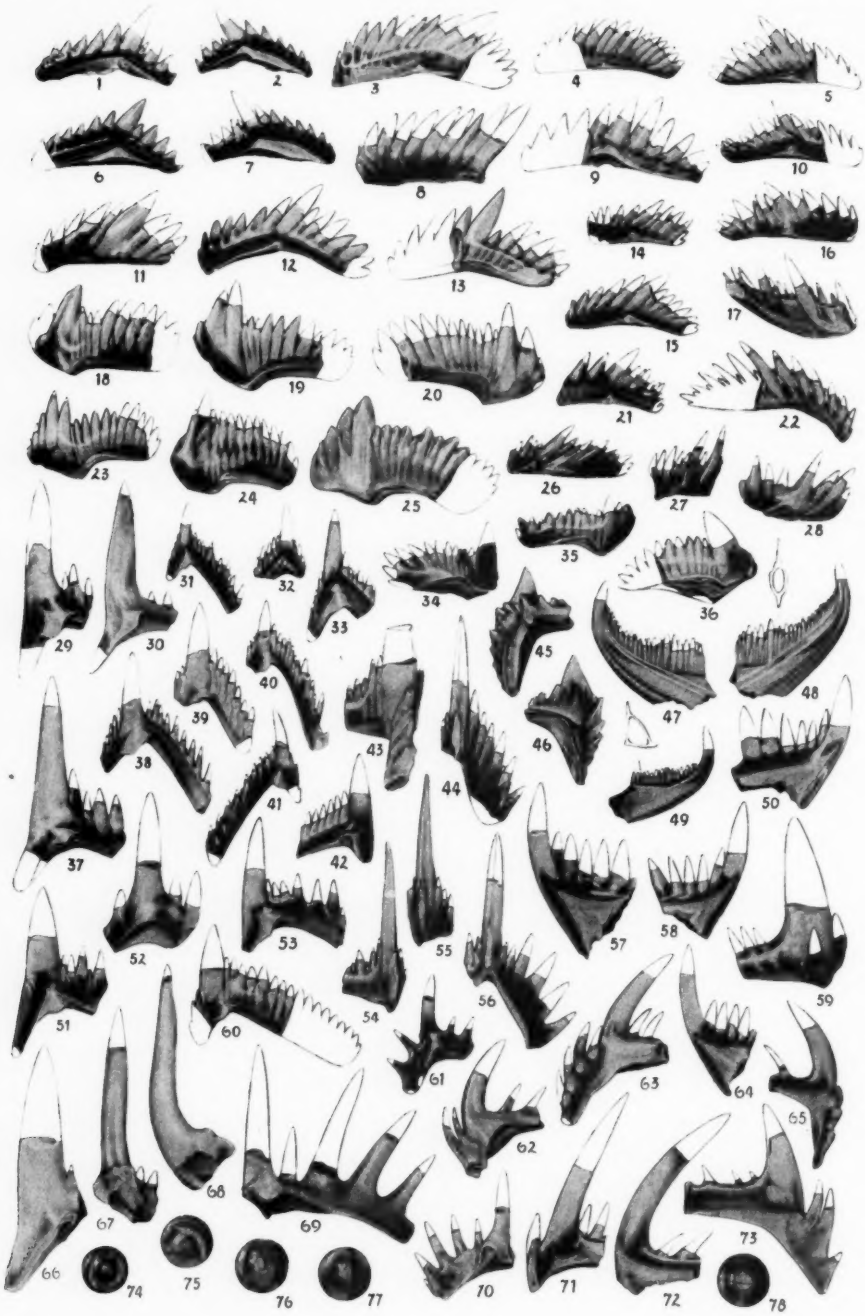
41—Polygnathus angulosus Stauffer, n. sp. Holotype, brick and tile plant, Austin, Minn., ×30. (p. 429)

42—Hindeodella? sp. Brick and tile plant, Austin, Minn., ×30. (p. 424)

43—Bryantodus sp. Brick and tile plant, Austin, Minn., ×30. (p. 421)



Stauffer, Devonian and Older Conodonts



Stauffer, Devonian and Older Conodonts

with deep pit beneath cusp, the outer margin of which is formed by the anticusp or downward projection of the cusp. Dental edge bearing one to two dozen closely crowded, markedly inclined, slender denticles, which may alternate in size, the smaller denticles barely erupting. Cusp laterally compressed, long and slender, curving slightly inward, and nearly parallel to the denticles. Downward projection or anticusp bearing four or five small denticles decreasing in size towards extremity.

EXPLANATION OF PLATE 59

FIGS. *1, 2, 6, 7—Ozarkodina concinna* Stauffer. Brick and tile plant, Austin, Minn., ×30. (p. 426)
3–5, 8—Ctenognathus elegans Stauffer. *3–5*, Brick and tile plant, Austin, Minn., *8*, Fowler and Pay quarry, Varco, Minn., ×30. (p. 422)
9—Bryantodus sp. Brick and tile plant, Austin, Minn., ×30. (p. 421)
10, 14–16, 21—Bryantodus versus Stauffer, n. sp. Syntypes. *10*, Homestead well, 1½ miles SW. of Austin, Minn.; *14–16, 21*, Brick and tile plant, Austin, Minn., ×30, except *21*, ×45. (p. 421)
11—Bryantodus? sp. Hickok quarry, LeRoy, Minn., ×30. (p. 421)
12—Ozarkodina congesta Stauffer, n. sp. Holotype, brick and tile plant, Austin, Minn., ×30. (p. 427)
13—Bryantodus sp. Hickok quarry, LeRoy, Minn., ×30. (p. 421)
17, 27—Cervicornoides sp. *17*, Brick and tile plant, Austin, Minn., ×30. *27*, Homestead well, 1½ miles SW. of Austin, Minn., ×45. (p. 422)
18–20, 24—Pandorina gratiosa Stauffer, n. sp. Syntypes, Hickok quarry, LeRoy, Minn., all ×30, except *19*, ×45. (p. 428)
22—Bryantodus? sp. Hickok quarry, LeRoy, Minn , ×30. ((p. 421)
23, 25—Pandorina insita Stauffer, n. sp. Syntypes. Hickok quarry, LeRoy, Minn., ×30 (p. 429)
26, 28—Bryantodus sp. *26*, Brick and tile plant, Austin, Minn., ×30. *28*, Hickok quarry, LeRoy, Minn., ×45. (p. 421)
29, 37, 51, 53, 66—Prioniodus remus Stauffer, n. sp. Syntypes *29, 51, 66*, Brick and tile plant, Austin, Minn. *37*, Underpass, Austin, Minn. *53*, Homestead well, 1½ miles SW. of Austin, Minn. All ×30. (p. 431)
30—Prioniodus taritus Stauffer, n. sp. Holotype, brick and tile plant, Austin, Minn., ×30. (p. 431)
31–33, 38–41—Synprioniodina forsenta Stauffer, n. sp. *31, 38–41*, Syntypes, brick and tile plant, Austin, Minn. *32*, Paratype, Homestead well, 1½ miles SW. of Austin, Minn. *33*, Paratype, brick and tile plant, Austin, Minn. All ×30, except *32, 33*, ×45. (p. 432)
34–36—Pandorina brambona Stauffer, n. sp. Hickok quarry, LeRoy, Minn. ×30. *35*, Holotype, *34, 36*, Paratypes. (p. 428)
42—Prioniodus sp. Brick and tile plant, Austin, Minn., ×45. (p. 431)
43, 44, 54–56—Dichognathus politus Stauffer, n. sp. Syntypes, brick and tile plant, Austin, Minn. *54, 55*, Opposite side views of one specimen. All ×45, except *44* and *56*, ×30. (p.422)
45, 46—Dichognathus protexus Stauffer, n. sp. Holotype, opposite side views, brick and tile plant, Austin, Minn., ×45. (p. 422)
47, 48—Belodus devonicus Stauffer, n. sp. Holotype, opposite side views, brick and tile plant, Austin, Minn., ×45. (p. 420)
49—Belodus triangularis Stauffer, n. sp. Holotype, brick and tile plant, Austin, Minn., ×45. (p. 420)
50, 57, 58, 64—Plectodina tilbara Stauffer n. sp. Syntypes, brick and tile plant, Austin, Minn., ×45. (p. 429)
52—Microcoelodus sp. Hickok quarry, LeRoy, Minn., ×45. (p. 426)
59—Trichognathus cf. *T. oxys* Cooper. Hickok quarry, LeRoy, Minn., ×30. (p. 434)
60—Synprioniodina tropa Stauffer, n. sp. Holotype, brick and tile plant, Austin, Minn., ×30. (p. 434)
61, 70—Trichognathus blanda Stauffer, n. sp. Syntypes, brick and tile plant, Austin, Minn.; *61*, ×45; *70*, ×30. (p. 434)
62, 63, 65, 71—Ligonodina armena Stauffer, n. sp. *63, 65*, Syntypes brick and tile plant, Austin, Minn. *62*, Paratype, brick and tile plant, Austin, Minn. *71*, Paratype, Homestead well, 1½ miles SW. of Austin, Minn. All ×30. (p. 425)
67—Trichognathus sp. Brick and tile plant, Austin, Minn., ×30. (p. 434)
68, 69—Microcoelodus sp. Brick and tile plant, Austin, Minn., ×30. (p. 426)
72—Subcordylodus sp. Brick and tile plant, Austin, Minn., ×45. (p. 432)
73—Ligonodina atana Stauffer, n. sp. Holotype, brick and tile plant, Austin, Minn., ×45. (p. 425)
74–78—Egg cases? Brick and tile plant, Austin, Minn., ×45. (p. 434)

Syntypes.—B 5596, B 5603–B 5606; paratypes, B 5597, B 5598; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone at the brick and tile plant and at the underpass, Austin, and at Homestead well, 1½ miles SW. of Austin, Minn.; also clay above the Cedar Valley limestone, Fowler and Pay quarry, Varco, Minn.

Synprioniodina tropa Stauffer, n. sp.
Plate 59, figure 60

Bar deep, straight except near anterior end, where it dips slightly downward; under side finely grooved, shallow pit beneath cusp protected on inner side by flaring lip and on anterior margin by anticusp. Dental margin bearing a series of similar deep-set denticles with alternating germ denticles that fail to erupt. Cusp large, laterally compressed, its anterior downward projection bearing several small denticles.

Holotype.—B 5622; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn., and upper part of Cedar Valley limestone, Hickok quarry, LeRoy, Minn.

Genus Trichognathus Branson and Mehl, 1933
Trichognathus blanda Stauffer, n. sp.
Plate 59, figures 61, 70

Limbs of base meet at angle of about 90°, with a medium to deep excavation chiefly confined to the angular space between limbs but extending up into base of cusp and laterally on underside of thin limbs as narrow groove. Dental edge of each limb bears two, three, four, or perhaps more slender discrete denticles of circular cross section. The cusp is slender, oval in cross section and with the inner elevated part at the base of the cusp curving into the upper margin of the sheath of the pit.

Syntypes.—B 5623, B 5632; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

Trichognathus cf. T. oxys Cooper
Plate 59, figure 59

Trichognathus oxys Cooper, *1939*, Jour. Paleontology, vol. 13, p. 422, pl. 46, fig. 46.

Base showing fragments of the two limbs of bar and their first denticles. Cusp large, subcircular to oval in cross section, with base curving rapidly inward to form the third limb, and with the rounded narrow curve of the oval forming the upper edge that bears three or four, possibly more, deeply inserted discrete denticles.

Figured specimen.—B 5621; Geological Museum, University of Minnesota.

Horizon and locality.—Upper part of Cedar Valley limestone, Hickok quarry, LeRoy, Minn.

Trichognathus sp.
Plate 59, figure 67

A fairly well preserved cusp with fragments of limbs. The cusp is fairly straight in upper part, tapers gradually, is flattened on outer side and highly convex on inner side, with center groove near base. At the lower end the cusp curves abruptly inward to form the posterior limb at right angles to main part of cusp. Denticles on lateral limbs probably short but sturdy.

Figured specimen.—B 5629; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone, brick and tile plant, Austin, Minn.

Egg cases?
Plate 59, figures 74–78

Spherical bodies of translucent amber-colored material. Slightly weathered specimens become white to opalescent and more or less opaque when dry. The centers of these bodies show small nuclear matter in spherical form and of about one-fourth the diameter of the complete sphere. The exact nature of these bodies or their possible significance is still unknown, but their general appearance, composition and occurrence with the conodonts suggests that they may belong to these animals.

Figured specimens.—B5636–B 5640; Geological Museum, University of Minnesota.

Horizon and locality.—Clay above the limestone at the brick and tile plant and at the underpass, Austin, Minn.

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JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 5, PP. 436–442, PL. 61, 1 TEXT FIG., SEPTEMBER, 1940

THE APICAL END OF ACTINOCERAS

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ABSTRACT—A specimen showing the apical end of *Actinoceras tenuifilum* (Hall) has a shallow initial chamber. The early siphuncular segments are nearly uniform in size and pass through stages reminiscent of *Polydesmia*, *Nybyoceras* and *Armenoceras*. The typical *Actinoceras* siphunuclar outline appears only after an abrupt expansion of the siphuncle. It is suggested that this ontogenetic sequence may represent the phylogeny of *Actinoceras*. Previous accounts of the apical ends of various Actinoceroidea are discussed. The Actinoceroidea and Endoceroidea agree in retaining a direct connection between the protoconch and siphuncle. Other Nautiloidea have a siphuncle that terminates in a closed apical caecum. This supports the division of the Nautiloidea into the Stenosiphonata and Eurysiphonata as proposed by Teichert.

A SPECIMEN of *Actinoceras tenuifilum* (Hall) retains the apical segments of the siphuncle and traces of the protoconch. The specimen was collected by the author and Mr. F. R. Flower from the Watertown member of the Black River limestone of the Middle Ordovician, on the banks of the Black River about two miles west of Watertown, N. Y. The features shown agree in general with those noted by Kobayashi(1937, pp. 1–21), in Asiatic Actinoceroidea, but the expansion of the siphuncle is more abrupt, and there is a more marked change in the siphuncular outline in the early segments.

The specimen represents a dorsoventrally sectioned part of a phragmocone consisting of 10 camerae (pl. 61, figs. 1–2; text fig. 1). In the adoral part the dorsum has been removed by weathering; in the adapical part the wall of the conch and the septa have been partly destroyed before burial. The first well-defined segment of the siphuncle has a diameter of 14 mm. and a length of 5 mm. The necks and brims are subequal, and their curvature is slightly more abrupt on the dorsum than on the venter. The outline of the segments is typical of the Actinoceratidae but lacks the angular condition of the brims that is characteristic of the early ephebic segments of *Actinoceras*. Rather the outline is essentially that of *Polydesmia* Lorenz (1906; emend. Teichert 1937).

The second segment is broader than the first and slightly shorter, having a diameter of 19 mm. and a length of 4 mm. The brim and neck are subequal, and the segment differs from the first mainly in its slightly different proportions. Segments 3–5 are almost identical in dimensions with segment 2, but come to lie closer to the venter and vary markedly in outline. In the third segment the outline of the siphuncle is that of *Nybyoceras* Troedsson (1926, p. 106), not that of *Actinoceras* Bronn (1837, p. 97; emend. Foerste 1924, p. 31; emend Troedsson 1926, p. 53, emend. Foerste and Teichert 1930, p. 224). On the venter the brim is recumbent, the inner tip of the neck is curved strongly apically. Dorsally the brim is strongly recurved but not recumbent. The area of adnation is greater on the dorsum than on the venter. The fourth segment is similar to the third. The fifth, which is very slightly broader, has the outline of *Armenoceras* Foerste (1924, p. 32), with the brim recumbent on both the dorsum and venter. From the fifth to the sixth segments there is an abrupt increase in the diameter of the siphuncle from 19 mm. to 23 mm., though the length of the segment remains the same. The dorsal neck is recumbent and is inclined apicad as on the venter of the preceding segments. The ventral part of the neck is obscure in the section but is either recumbent or nearly so. The succeeding four segments are typical in outline of early ephebic *Actinoceras*. The brims are angulate but free. The angulate condition of the brims is lost in *A. ruedemanni* Foerste and Teichert at a dorsoventral diameter of 40 mm., where the siphuncle ceases to lie in contact with the ventral wall of the conch. It has not been possible to determine at what point the change occurs in *A. tenuifilum* (Hall).

The central canal is subcentral in the ad-

oral portion of the specimen. Its course in the middle is not exposed in the section, but it is seen again in the apical segments, where it lies close to the venter. In the adapical segment two radial canals can be seen. One extends straight to the perispatium on the ventral side (fig. 1, *a*); the other (*b*) follows a rather devious course dorsad, and before attaining the perispatium on the dorsal side sends out two branches, which extend apicad and terminate in the cavity of the protoconch, close to the dorsal and ventral terminations of the first septum. (Pl. 61, fig. 1–2; text fig. 1.) The dorsal of these two canals (*d*) is greatly enlarged. The ventral one (*c*) is slender. Close to the termination of the ventral canal lies a fragment of the wall of the protoconch still in position, hiding the aperture of the canal from a direct apical view. The protoconch has been destroyed on the dorsal side, so that the aperture of the dorsal canal is more exposed. It is possible that its enlarged condition may be due to solution.

The apical septum shows no trace of septal necks, but its free tip is covered on both dorsum and venter by dense carbonic material, which suggests the perispatial deposits in texture. The material of the annulosiphonate deposits has penetrated the protoconch. Besides the two canals already mentioned, which are a part of the radial canal system, there is a broad median notch (*e*) in the deposit, which suggests that the central canal may attain the protoconch, though its course does not lie in the plane of the section. If so, the central canal must turn dorsad from its position in the second siphuncular segment, as Kobayashi has found it to do in *Armenoceras*.

The protoconch is only partly preserved, the central part being missing. The conch evidently contracts very rapidly adapically, and the protoconch is an exceedingly short chamber. Kobayashi (1937, p. 6, text fig. 1) has represented the protoconch as a short chamber which forms a slight protuberance on the blunt apex and supplies a hump on an otherwise regularly contracting outline. In *Actinoceras* the form of the protoconch seems to be more in keeping with the outline of the conch as a whole. On the venter a fragment of the wall of the protoconch lies parallel to the first septum but is separated from it over a considerable area by the cavity of the protoconch, which is here exceedingly shallow and is filled with calcite representing original organic deposit. (Pl. 61, fig. 2.) On the dorsal side, the greater part of the wall of the protoconch is likewise subparallel to the septum, but it appears to arch abruptly toward the center. Here the wall of the protoconch is represented by a dark-brown band of irregular outline. The irregularity seems to indicate that some foreign substance was attached to the shell. There is no evidence of a shallow but bulbous protoconch such as Kobayashi has represented in his specimens.

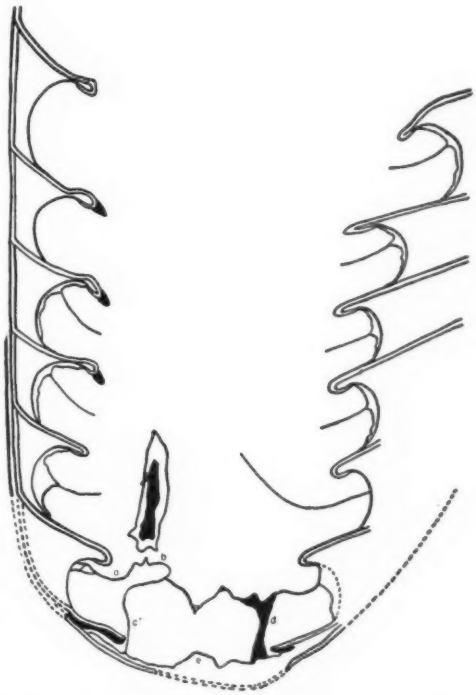


FIG. 1.—Camera lucida drawing of the apical end of *Actinoceras*, showing details of siphuncular outline, restored and preserved outline of the protoconch, and the central and radial canals of the apical segments. The lettering is explained in the text.

The radial canal system is of the *Actinoceras ruedemanni* type (Teichert, 1933; 1935, p. 9), consisting of canals curving orad from the perispatium toward the central canal. The structure is the same throughout, and

there is no indication of the *Nybyoceras* type (Teichert, 1935, p. 9), which might be expected in segments with *Nybyoceras* and *Armenoceras* types of outlines, for those genera are characterized by the *Nybyoceras* type of radial canal system. Clearly the radial canals do not show ontogenetic phases comparable to those shown by the outline of the siphuncular segments.

ONTOGENY OF THE SIPHUNCLE

The abrupt change in the size of the siphuncle is of particular interest. The almost identical size of segments 3–5 seemed at first to represent a pathological condition, but Kobayashi has found identical features, though not quite as pronounced, in three specimens of *Armenoceras richthofeni* Kobayashi, two specimens of *A. manchurense* Kobayashi, and one of A. *intermedium* Kobayashi.

Preceding the zone of expansion lie segments that are rather variable in form. Kobayashi's (1937, pl. 1, fig. 2) figure of *Selkirkoceras yokusense* (Kobayashi) shows in the apical segments the recumbent brim and the strong area of adnation that characterize *Armenoceras*. Gradational stages in succeeding segments lead finally to a type of siphuncular outline in which the brims are free and the structure characteristic of an *Actinoceras* or *Kochoceras* is attained. This is typical of *Selkirkoceras* Foerste (1929, p. 199), and the transition from an *Armenoceras* stage to an *Actinoceras* stage is too gradual to be striking. Further, there is no zone of abrupt siphuncular expansion, and the ephebic proportions are attained gradually. However, in *Actinoceras* the succession of outlines is more striking, and the ontogenetic stages that show outlines characteristic of other genera are set apart from the normal ephebic structure of *Actinoceras* by a marked expansion of the siphuncle. It was suspected that the stages represented in the ontogeny of *Actinoceras* might represent the phylogeny of the genus. Such an interpretation is not inconsistent with the stratigraphic evidence. *Actinoceras* and *Armenoceras* both appear in the Middle Ordovician, and either might be derived from the other as far as the stratigraphic distribution is concerned. *Nybyoceras* is older, being particularly characteristic of the Chazyan of America, though extending higher into the section in Asia. As was pointed out above, the *Actinoceras*-like outline of the first two segments is not consistent with the early ephebic structure of *Actinoceras*, but only with the metephebic and gerontic segments; on the other hand it reproduces a type of outline found in *Polydesmia* Lorenz (= *Maruyamaceras* Kobayashi 1931, p. 52), a genus which is characteristic of the Maruyama bed of the Wolungian of Manchuria, the equivalent of our Canadian, and is the oldest known representative of the Actinoceroidea. The successive stages as shown in the ontogeny of *Actinoceras* are consistent with the appearance of the genera in the stratigraphic column. When we take into consideration the present scheme of classification of the Actinoceroidea (Teichert, 1934, p. 5) we find that there are some discrepancies. The two genera in the middle of the series, *Armenoceras* and *Nybyoceras*, belong to the Armenoceratidae, but the beginning and the end of the series, *Polydesmia* and *Actinoceras*, belong to the Actinoceratidae. The desirability of a revision of the families seems to be indicated. Under the present scheme of classification there are stratigraphic perplexities. One cannot but wonder that the Actinoceratidae are represented in the Wolungian (Canadian) by *Polydesma* and in the Middle Ordovician by numerous other genera, while only Armenoceratidae and Sactoceratidae appear in the Lower Ordovician. Revision is further indicated by the diversity of radial canal structure in the Armenoceratidae.

The radial canal system is not as well preserved in the specimen of *Actinoceras* under discussion as might be desired, but it is adequate to show that the *Actinoceras ruedemanni* type of structure is uniform throughout, and the only unusual feature is the structure of the radial canals in the initial segment.

OTHER APICAL ENDS OF ACTINOCEROIDEA

The two specimens of *Selkirkoceras* Foerste known from America obviously represent apical ends because of their bluntly subconical form. The large size and markedly depressed section of both species suggests *Kochoceras* Troedsson. In *S. cunea-*

tum Foerste (1929, p. 199, pl. 31, fig. 2A–B), the outline of the first two or three segments of the siphuncle is not known. The four illustrated segments are all of the same width and length and in outline resemble the segments of *Armenoceras*. The section is transverse and cannot be expected to show any trace of a *Nybyoceras* stage, which depends on differences in the dorsal and ventral outlines of the siphuncle. The segments shown are all of the same width and length and bear a strong resemblance to the segments found in *Actinoceras* just preceding the region of abrupt siphuncular expansion. In *S. tyndallense* Foerste (1929, p. 210, pl. 31, fig. 1A–D), the siphuncle contracts gradually away from the wall of the conch, as in *S. yokusense* (Kobayashi). Here also the apical segments are of the *Armenoceras* type, but adoral segments grade into the type of outline characteristic of *Kochoceras* Troedsson. The evidence would suggest that *Selkirkoceras* might represent the apical end of *Kochoceras*. Certainly it would be very difficult if not impossible to distinguish the genera without the early stages. Further, it might appear that there are two types of early stages, one in which segments of a uniform size are followed by an abrupt expansion, and another in which the siphuncle contracts gradually from large apical segments to smaller adoral ones.

Among the specimens of *Kochoceras* that have been figured are a considerable number of individuals that represent apical or nearly apical portions of the conch. The siphuncle is uniformly broad apically, and the first segment is not only considerably inflated but is somewhat longer than the others. This condition has been found in the following species, of which the first is from the Red River beds of Manitoba, and the others are from the Cape Calhoun series of northern Greenland, both Upper (?) Ordovician: *K. tyrelli* Foerste (1929, pl. 28, fig. 1), *K. cuneiforme* Troedsson (1926, pl. 39, fig. 1; pl. 44, fig. 6), *K. cuneiforme* var. *robustum* Troedsson (1926, pl. 42, fig. 4), *K. ellipticum* Troedsson (1926, pl. 42, fig. 2), *K.* sp. aff. *K. ellipticum* Troedsson (1926, pl. 43, fig. 3), *K. ellipticum* var. *minutum* Troedsson (1926, pl. 44, fig. 3), and *K. productum* Troedsson (1926, pl. 44, figs. 4, 5). These all agree with *Selkirkoceras tyndallense* in the gradual contraction of the siphuncle but differ in having a siphuncular outline typical of *Kochoceras* throughout. We are forced to conclude, therefore, that although *Selkirkoceras* and *Kochoceras* are ephebically convergent, the early stages indicate either a very different origin for the two, or else that *Kochoceras* has lost all vestiges of the ancestral stages by tachygenesis. In view of the fact that *Selkirkoceras* and *Kochoceras* occur together in the Red River beds, and that both the Red River and Cape Calhoun beds are referred to the same age, tachygenesis is not a convincing explanation.

Kochoceras illustrates another point. Kobayashi (1937, p. 3) has suggested that inasmuch as siphuncles with and without regions of abrupt pre-ephebic expansion appear in the same genus, it is possible that sexual differences are involved, and that the development of sexual organs of the female in the siphon might account for the abrupt expansion in that sex, while the less bulky sexual organs of the male would produce a much less marked change. There are no sexual organs in the siphon of *Nautilus*, but that proves nothing. *Nautilus* is the last survivor of one specialized line; the Actinoceroidea represent another line, appearing early but none the less highly specialized, and it is unsafe to apply generalizations based on *Nautilus* to the Actinoceroidea, or to orthoceracones as a whole. However, it might be noted that all of the siphuncles of *Kochoceras* from northern Greenland are of the same type, further, a type in which there is a very gradual contraction from a large initial segment, and no abrupt expansion. If the sexual dimorphism hypothesis is to be applied to these forms we cannot but remark that it is strange that all of the specimens from the Cape Calhoun locality represent the supposed males of the species.

Teichert's (1934, p. 16, fig. 4) reconstruction of the apical end of the Actinoceroid is based upon the Greenland material mentioned above. Apparently the true apical chamber was missing from all specimens, but a feature brought out by his studies is the absence of a brim or neck on the apical septum.

Schindewolf (1935, p. 92) has figured and described a new species and genus of actinoceroid, *Carbactinoceras torleyi*, the holotype

of which retains, according to his description, the apical end. The specimen presents several features at variance with those noted independently by Kobayashi and the present author in Ordovician species. The more striking differences shown by *Carbactinoceras* are as follows: 1, The apical chamber is slightly longer than the following camerae, but the siphuncle is of normal width, that is, expanding gradually with the diameter of the conch. 2, The apical septum has well defined necks and brims and differs in no way from the others. 3, The siphuncle evidently ends in a closed apical caecum. 4, There is no trace of change in the siphuncular outline.

Kobayashi (1937, p. 7), largely on the basis of the form of the wall of the conch, suggested that the earliest segment shown by Schindewolf might represent the true apical chamber. The section is transverse, as is shown by the equal development of cameral deposits on both sides. A horizontal section passing through the central canal, as this one does, would necessarily miss the tip of the canal in the first camera where it begins to turn dorsad. The result would be precisely that shown in the apical segment of *Carbactinoceras*. The extreme apex of the specimen is missing, and the closure of the siphonal caecum is hypothetical. It is here considered more probable that the true apical chamber is not represented in Schindewolf's specimen, and that the apical part of the specimen shows only the first siphuncular segment, beyond which there should occur another septum, this time without brim or connecting ring, preceded by the true apical chamber.

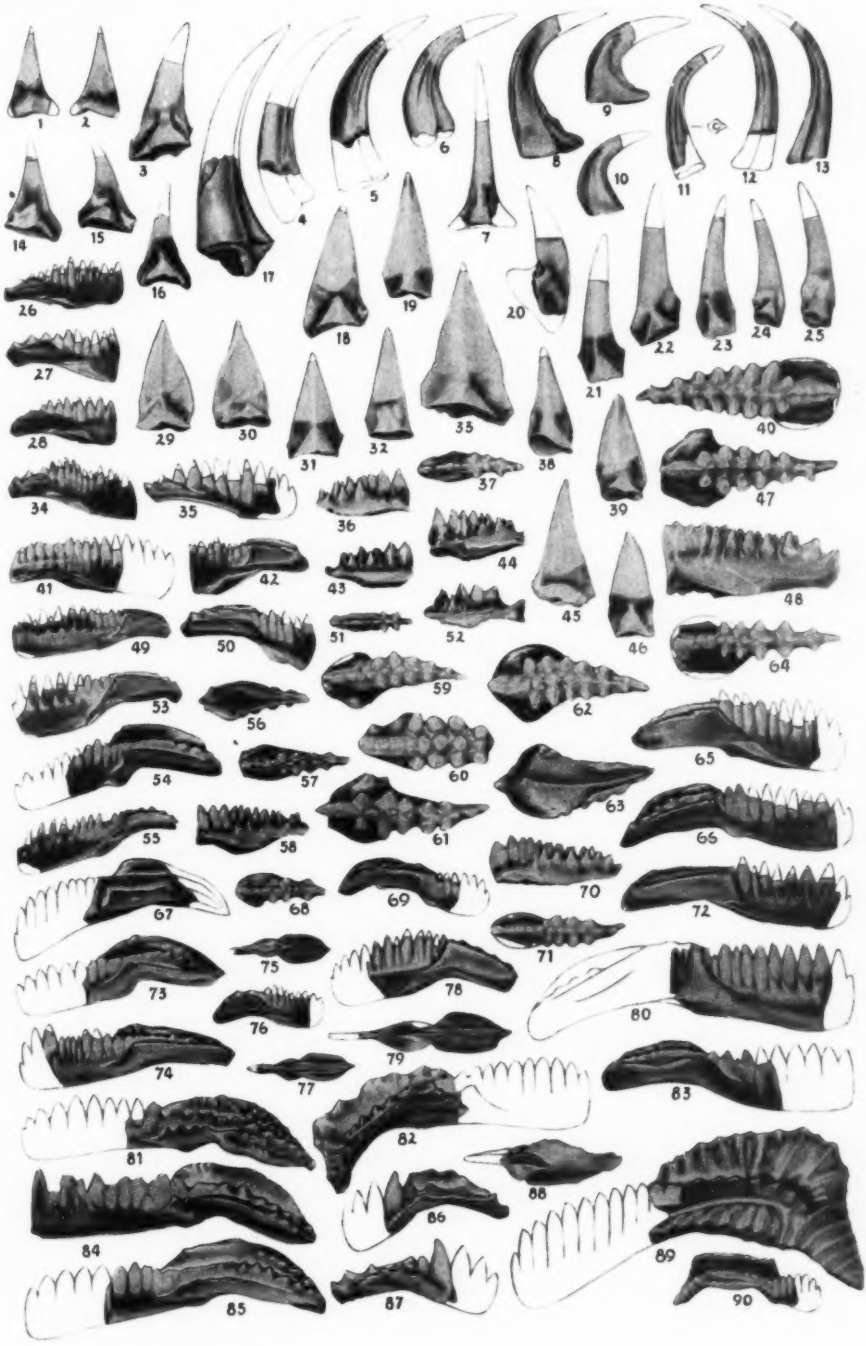
Obviously there is considerable variation in the size and form of the early segments of the siphuncles of the Actinoceroidea. There may or may not occur a succession of ontogenetic stages that recall the siphuncular outlines of other genera than the one to which the species belongs. *Actinoceras* and *Selkirkoceras* show such stages. They are apparently lacking in *Kochoceras*, *Armenoceras* and *Carbactinoceras*. A specimen of *Elrodoceras indianense* (S. A. Miller) from the Laurel limestone of Indiana in the collection of the author retains segments which approach if they do not attain the first, yet there is no modification of siphuncular outline.

SIGNIFICANCE OF THE PROTOCONCH

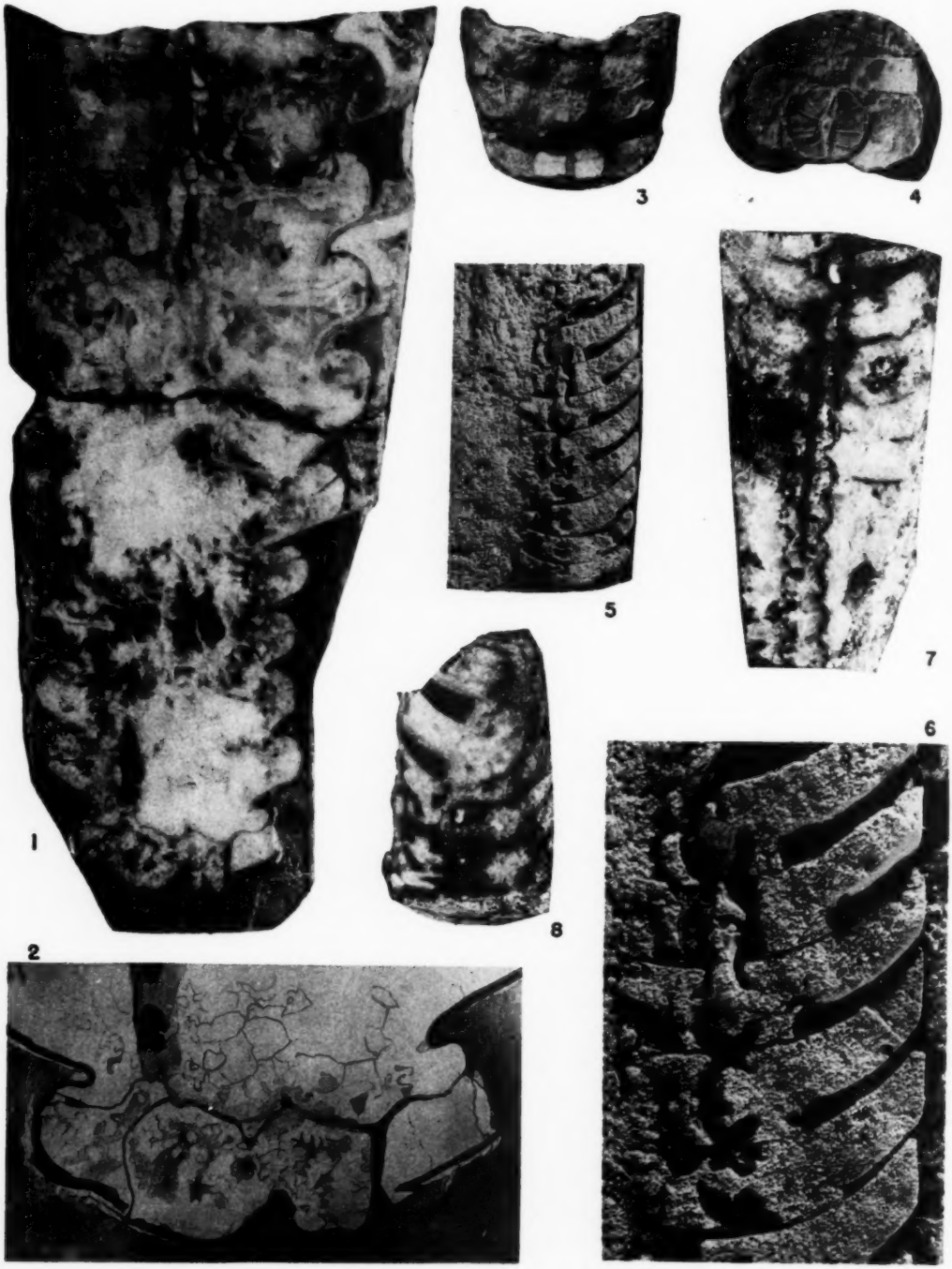
The form of the protoconch has been so significant in the Ammonoidea that we have perhaps come to expect too much of its form in the Nautiloidea. The protoconch of the Actinoceroidea is a small, very shallow chamber, perhaps with a slight apical swelling and perhaps not. The point does not seem a particularly significant one. The remarkably small size of the protoconch of the Actinoceroidea in relation to the immediately adjacent part of the conch does not at once recall features known in any other group of cephalopods. Internal features may be more significant.

All authors appear to be in agreement concerning the termination of the siphuncle in a closed apical caecum in the majority of the Nautiloidea. There remains, however, considerable difference of opinion as to whether the apical caecum occupies the true protoconch, or whether the true protoconch lies still farther apicad and, being chitinous, has been destroyed. The closed caecum is found in *Nautilus* and in orthochoanitic forms in general. It also appears in a number of cyrtochoanitic groups including the Pseudorthoceratidae, late Paleozoic cyrtoceracones of uncertain affinities, and some apparently actinosiphonate forms. In sharp contrast to this there is another group, in which the siphonal caecum is not developed, but in which the siphuncle is open apically and communicates directly with the protoconch. On this basis it might be possible to follow the present trend and propose two new major divisions for the Nautiloidea, with names based upon the striking differences that one group is characterized by a closed siphon, the other by an open siphon. Names on such a basis are unnecessary, for these groups appear to coincide exactly with the Eurysiphonata and Stenosiphonata of Teichert (1933). The groups were based upon ephebic characters, the length of the septal neck, and the general size of the siphuncle. The Eurysiphonata include the Holochoanites of Hyatt and the Actinoceroidea,

(*For explanation of Plate 60, see bottom of page 423*)



Stauffer, Devonian and Older Conodonts



Flower, Ordovician and Devonian Cephalopods

in both of which the necks are relatively long and the siphuncles relatively large. The Stenosiphonata include all other forms, in which the siphuncle is narrow and the septal necks are short. The Sactoceratidae of the Actinoceroidea supplies an exception to both characters, and it is frequently impossible to distinguish a *Sactoceras* from such stenosiphonate genera as *Stereoplasmoceras* Grabau or *Pseudorthoceras* Girty. Further, adoral segments of the siphuncles of Cincinnatian Actinoceroidea, probably best referred to *Paractinoceras* Hyatt, approach and attain an outline essentially orthochoanitic. These are very real practical difficulties, but do not supply valid objections to the wide distinction between the Actinoceroidea and the stenosiphonate forms. The Actinoceroidea can be recognized at once wherever a specimen is complete enough, for in the apical part of the phragmocone the siphonal deposits have outlined the radial canal system and the perispatium, features which hold throughout the superfamily and are confined to it.

The size of the protoconch is apparently not a very significant factor. The long apical chamber of *Nanno*, with a relatively late appearing septate portion, is obviously the homologue of the abbreviated chamber of *Suecoceras* in which the appearance of the camerae has been accelerated. Further acceleration may produce an even shallower chamber, like that of *Actinoceras*. The Endoceroidea and Actinoceroidea cannot be said to merge. The enclosure of a space by a single apical septum in *Nanno* affords a sharp contrast to the free termination of the septum without brim or neck in the *Actinoceroidea*. Nevertheless the retention of the open connection between the protoconch and the siphuncle in the Eurysiphonata presents a very significant feature that sets it apart from the Stenosiphonata. As Schindewolf (1935, p. 101) has suggested, the open protoconch seems to reflect a stage in the evolution of the Nautiloidea previous to the appearance of septation. The development of septation supplies a single change, in which unneeded spaces are partitioned off. There is at first no good break between the cavity of the protoconch and that of the siphon and living chamber. The development of the siphonal caecum, supplying such a break, must have been coenogenetic, and should serve to set off the Stenosiphonata and Eurysiphonata sharply from each other.

ACKNOWLEDGMENT

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EXPLANATION OF PLATE 61

FIGS. *1, 2*—*Actinoceras tenuifilum* (Hall) *1*, Vertical section with venter on left, showing the apical end and the early siphuncular segments. The fragments of the protoconch are not clearly shown. *2*, Camera lucida drawing, ×4, of the apical end of the same specimen, showing fragments of the protoconch, details of the first septum, and the radial canals. Paleont. Research Inst. no. 5868. Black River limestone, Middle Ordovician, Watertown, N. Y. (p. 436)

3, 4—*Metarmenoceras bilaterale* Flower, n. sp. Holotype, ×1. *3*, Ventral aspect, with apical siphuncular segment sectioned. *4*, Adoral aspect, showing natural section through the middle of the segment, with ventral process of the central canal and paired radial canals. New York State Mus. no. 12379e/1. Dalhousie beds, Lower Devonian, Gaspé. (p. 445)

5, 6—*Ormoceras schohariae* Flower, n. sp. Paratype, natural section. *5*, ×1. *6*, Enlargement of a portion of the same, ×2, showing details of the siphonal structures. Paleont. Research Inst. no. 5869. Schoharie grit, Middle Devonian, Albany County, N. Y. (p. 443)

7, 8—*Ormoceras centrale* Flower, n. sp. Holotype, ×1.2. *7*, Dorsoventral section, parallel to bedding. Siphonal deposits are slightly heavier on the ventral (right) side. *8*, Section normal to bedding, showing distortion and fracture of the septa due to pressure, also the incipient phase of annulosiphonate deposits. Paleont. Research Inst. no. 5870. New Scotland limestone, Lower Devonian, Schoharie, N. Y. (p. 444)

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SOME DEVONIAN ACTINOCEROIDEA

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ABSTRACT—Revisionary notes on the family Sactoceratidae of the Actinoceroidea are presented in this paper. The form of the radial canals is proposed as a more satisfactory guide to the phylogeny in the Actinoceroidea than the outline of the siphuncle, ordinarily used. On this basis *Rayonnoceras* is a member of the family Sactoceratidae; likewise species currently referred to *Armenoceras* appear to belong here. Two new species of *Ormoceras*, *O. centrale* of the Helderbergian and *O. schohariae* of the Schoharie grit are described, and a new genus and species, *Metarmenoceras bilaterale* is described from the Dalhousie beds (Lower Devonian) of Gaspé.

FOERSTE and Teichert (1930, p. 220) remarked upon the absence of Actinoceroidea from the Devonian, although it is represented by several genera in the Silurian and by the genus *Rayonnoceras* Croneis in the Mississippian. Clarke (1909, pl. 22, fig. 16) had previously figured as *Orthoceras* sp. a specimen, evidently an actinoceroid, found loose in Presque Isle stream, Arostook County, Maine, which is probably from the Chapman sandstone of the Lower Devonian. Teichert (1933) later figured this as *Ormoceras* sp. The genus is principally Silurian in range. Foerste had previously described *Ormoceras* from the Lower Devonian of Novaya Zemlya (1925) and Nova Scotia (1928).

In the Helderbergian of the Lower Devonian of New York *Ormoceras* is the most abundant orthoconic genus, but the material is for the most part too poorly preserved to permit accurate specific indentification. One species is described below, *Ormoceras centrale*. More surprising is the presence of *Ormoceras* in the Schoharie grit of the Middle Devonian.

Metarmenoceras, a genus erected for the reception of a single species, *M. bilaterale* Flower, n. sp., of the Dalhousie beds of the Lower Devonian of Gaspé, is thus far the only genus of Actinoceroidea which is known only from the Devonian. This genus, as well as *Ormoceras*, is referred to the Sactoceratidae.

The family Sactoceratidae was set off from the other families of the Actinoceroidea by Foerste and Teichert (1930, p. 208) on the basis of the small size of the siphuncle and the short septal necks, which distinguish it from the Actinoceratidae, and by the only slightly recurved brim, by which it can be distinguished from the Armeno-

ceratidae. Such divisions are not, however, as satisfactory as they might at first appear. Cincinnatian species, probably best referred to *Ormoceras*, show affinities with *Armenoceras* in the abruptly recurved necks of the earlier siphuncular segments. Later siphuncular stages exhibit outlines characteristic of *Ormoceras*, *Sactoceras*, *Deiroceras* and *Leurorthoceras* in turn. Thus a variety of genera can be recognized from fragments of a single individual, and from preliminary investigations it appears that not a few of the species of "*Orthoceras*" of the Cincinnatian may represent various stages of the same species.

In the Sactoceratidae are now included the following genera: *Sactoceras* Hyatt, *Ormoceras* Stokes, *Deiroceras* Hyatt, *Cyrtactinoceras* Hyatt, *Leurorthoceras* Foerste, and *Troedssonoceras* Foerste. The family is distinct from the Actinoceratidae, but not, in its present condition, from the Armenoceratidae, for sactoceroid forms grade into the genus *Armenoceras*. Possibly the form of the siphonal vascular system may serve to fix a more natural boundary. Some species of Armenoceras possess the *Nybyoceras* type of radial canal system (Teichert, 1935, p. 9); others have the straight and simple canals typical of *Ormoceras*. Such forms have relatively small siphuncles and may be more closely related to *Ormoceras* than to species of *Armenoceras* possessing the *Nybyoceras* type of radial canal system, which is typically associated with considerably larger siphuncles.

A more definite addition to the Sactoceratidae is the genus *Rayonnoceras* Croneis. Features of this genus typical of the family are the short septal necks and the straight radial canals normal to the central canal. *Rayonnoceras* was placed in the Actinoceratidae by Foerste and Teichert on the basis of the large size of the siphuncle. Yet the siphuncle is smaller in relation to the rest of the conch than in other Actinoceratidae and only appears large because *Rayonnoceras* attains a very large size and its phragmocone is often partly destroyed. Structural features suggest that the genus might better be placed in the Sactoceratidae. This is supported by the stratigraphic evidence. The other genera of the Actinoceratidae, which appear to form a good genetic group, do not survive the end of the Ordovician. The Sactoceratidae are now known to attain the Middle Devonian, thereby considerably narrowing the gap which had previously isolated *Rayonnoceras* from other Actinoceroidea. The first *Rayonnoceras* appears in Europe in the Visé limestone (middle Mississippian) of Belgium. American forms rangs from those found in boulders of supposedly St. Louis (late middle Mississippian) age in the Caney shale, upward to one described from the Bend sequence of the basal Pennsylvanian.

ORMOCERAS SCHOHARIAE Flower, n. sp.
Plate 61, figures 5, 6

Orthoceras luxum, Hall. HALL, *1879*, Paleontology of New York, vol. 5, pt. 2, pl. 77, fig. 6, 8; pl. 78B, fig. 3.—GRABAU and SHIMER, *1910*, North American Index Fossils, vol. 2, p. 113, fig. 1347.

This species is not conspecific and is probably not congeneric with *Orthoceras luxum* Hall, but was originally included and illustrated under that name. The species is known from portions of the phragmocone ranging in diameter from 8 mm. to 25 mm. The conch is orthoceraconic, slender, with an increase in dorsoventral diameter of 2 mm. in a length of 20 mm. The section is slightly depressed. At the apical end of the holotype the dorsoventral diameter is 12 mm., with the transverse diameter estimated at 18 mm. The specimen is sectioned dorsoventrally.

Sutures straight and transverse. Four camerae occupy a length equal to an adoral diameter of 15 mm. to 25 mm. In earlier portions of the conch the camerae are slightly deeper in proportion to the diameter, so that there are three in a length equal to an adoral diameter of 10 mm. Septa are slightly deeper than the camerae and are evenly curved. At a dorsoventral diameter of 21 mm. the septum is 6 mm. in depth; the camera 5 mm. in depth. The siphuncle lies slightly ventrad of the center. In the holotype the septal foramen at the apical end of the specimen is 1 mm. in diameter and is located 5 mm. from the venter and 6 mm. from the dorsum. The segments are subspherical. Where the depth of a camera is 5 mm., the siphuncular segment expands from 2.5 mm. to 5 mm. The necks are about one-sixth the length of the segment, evenly

recurved, with brim and neck subequal. The connecting ring is evenly convex throughout and is adnate at the adapical end for a length equal to the brim. The deposits of the siphuncle are very obscure in the holotype, as seen in a polished section, but are well preserved in a natural weathered section of a paratype from which all calcareous material has been removed. Here the central canal, straight radial canals, and the perispatium can be seen. Episeptal deposits occupy the camerae. There is no trace of hyposeptal deposits. The living chamber, aperture and surface of the shell are unknown.

Discussion.—This is one of several species included by Hall under *Orthoceras luxum.* The first specimen illustrated, the only one illustrated in connection with the original descriptions of the species, is too poorly preserved to serve as a basis for the recognition of the species. The lax condition of the camerae was considered diagnostic of *O. luxum* by Hall. This condition is due to the removal of mural or episeptal cameral deposits. Such deposits are too widespread to be diagnostic of the species, and details of lobation are not sufficiently clear to serve as specific criteria owing to poor preservation. Further, *Ormoceras schohariae* differs from "*Orthoceras*" *luxum*, in having a naturally depressed section and camerae which are considerably deeper, especially in the adapical part of the phragmocone.

This species represents the latest occurrence of *Ormoceras* so far recorded. The outline of the siphuncle is typical of the genus, and there is no trace of the gerontic modification which distinguished *Sactoceras.*

The holotype has been sectioned along a plane slightly inclined from the plane of symmetry. It shows the exterior of the internal mold, the section and the position of the siphuncle. The structure of the interior is not, however, well displayed. The paratype represents a natural section of a slightly later stage and retains the features of the siphuncle, siphonal deposits, and cameral deposits remarkably well. This specimen attains the dimensions of the holotype of "*Orthoceras*" *luxum*, which can be distinguished by the shallower camerae, there being seven in a length equal to the diameter at this stage rather than four.

Types.—Holotype: New York State Museum no. 12380/15. Paratypes: New York State Museum no. 12380/13; Paleont. Research Inst. no. 5869.

Occurrence.—From the Schoharie grit of the Middle Devonian, from Schoharie, N. Y. and from Wolf Hill, Albany County, N. Y.

Ormoceras centrale Flower, n. sp.
Plate 61, figures 7, 8

Conch orthoceraconic, apparently slightly depressed in section originally. The upper surface of the holotype is badly crushed. The specimen expands from 19 mm. and 10 mm. to 28 mm. and 19 mm. in a length of 53 mm.; and to 32 mm. and 20 mm. in the next 30 mm. It is believed that the under surface represents the normal condition, though it is possible that the transverse diameter has been increased by pressure, as the transverse rate of expansion is about 2 mm. in a length of 10 mm., which is unusually large, and is slightly irregular.

Sutures straight and transverse on the under side. A faint saddle on the upper side is probably due to distortion. The curvature of the septa is unknown, having been modified by pressure. Four and one-half camerae occupy a length equal to the adoral transverse diameter of 32 mm.

Siphuncle in horizontal section is equidistant from the sides and must have been central or subcentral in position. Where the diameter of the conch is 24 mm., the siphuncular segment expands from 4 mm. to 6 mm., and is 5 mm. long. The septal necks are about one-fifth the length of the segment, recurved, with the brim slightly less than the neck. The connecting rings are narrowly adnate adapically to the preceding septum. The interior of the siphuncle contains deposits characteristic of *Ormoceras.* In horizontal section, i.e., parallel to the original bedding, the deposits are developed more strongly on the right than on the left side, suggesting that the section may be dorsoventral rather than horizontal with reference to the orientation of the organism. Central and radial canals are well developed. The perispatium is filled at the adapical end in each segment with perispatial deposits but is empty adorally. Episeptal deposits occupy the camerae, but no hyposeptal deposits are developed.

Discussion.—The species can be readily recognized by the central position of the siphuncle. Thus far it is the only species of *Ormoceras* known in the Lower Devonian of North America. The proportions will distinguish this species from *Ormoceras schohariae* of the Schoharie grit.

The holotype is sectioned in two parts. A section parallel with the bedding was made in the adapical portion (pl. 61, fig. 7), and a vertical section was taken through the adoral portion (pl. 61. fig. 8). This section shows distorted and broken septa indicative of flattening. If, as is assumed, the horizontal section is dorsoventral, the apparent modification of the sutures is confined to one lateral surface and is therefore due to distortion rather than to any original condition.

Type.—Holotype: Paleont. Research Inst. no. 5870.

Occurrence.—From the New Scotland limestone, Helderbergian, Lower Devonian, from Schoharie, New York.

Genus METARMENOCERAS Flower, n. gen.

Genotype, *Metarmenoceras bilaterale* Flower, n. sp.

Conch orthoceraconic, slightly depressed in section. Sutures straight and transverse, curvature of septum normal. Siphuncle ventrad of the center, its segments broadly nummuloidal, twice as wide as long. The brims are more than twice the necks, although free, and the area of adnation exceeds the brim. The central canal differs from that of all other Actinoceroidea in being compressed and attaining the wall of the siphuncle on the venter. Radial canals are normal to the central canal, straight, and are formed in the middle of each segment. The radial canals are arranged in pairs forming a bilaterally symmetrical pattern with some occasional irregularities due to branching. All but the ventral pair originate from the center of the siphuncle; the ventral pair springs from the sides of the ventral process of the central canal. The camerae contain both episeptal and hyposeptal deposits.

Discussion.—The outline of the siphuncle is identical with that found in many species referred to *Armenoceras*. Species referred to *Armenoceras* likewise possess straight radial canals normal to the central canal. The genus is unique, however, in its compressed central canal and its bilaterally symmetrical arrangement of the radial canals. *Armenoceras* itself is not known to extend into the Devonian. The youngest species known to me are two undescribed forms from the Cobleskill limestone of the Upper Silurian of New York.

METARMENOCERAS BILATERALE Flower, n. sp.

Plate 61, figures 3, 4

Orthoceras cf. *longicameratum* Clarke, *1909*, New York State Mus., Mem. 9, vol. 2, p. 21, pl. 1, fig. 9.

The holotype is part of a phragmocone consisting of only four camerae. The ventral side is somewhat weathered. Section depressed. At the adoral end of the specimen the transverse diameter is 31.5 mm. The siphuncle is 10 mm. in diameter and is 10 mm. from the dorsal or antisiphonal side. The estimated dorsoventral diameter is 25 mm. Septum evenly curved, 5 mm. in depth where the transverse diameter is 29 mm. Sutures straight and transverse. Camerae shallow, six occurring in a length equal to an adoral transverse diameter of 31.5 mm.

The segments of the siphuncle are nearly twice as broad as long. A segment 5 mm. in length expands from 6 mm. to 9.5 mm. The brim is about three times the length of the neck but is free. The area of adnation is slightly greater than the brim. The interior of the siphuncle contains well-developed deposits, and the canal system is well preserved. The central canal is compressed throughout. In the middle of each segment it is so extended that it attains the wall of the siphuncle on the midventral line. At the same level the radial canals are produced, forming a radiating bilaterally symmetrical pattern. These canals are well exposed on the natural section at the adoral end of the specimen. Five pairs can be recognized. The ventral pair springs from the ventral process of the central canal. The second pair is divided on the left side as oriented in the illustration but is simple on the right. The succeeding two pairs are normal and spring from the center of the siphuncle. The two members of the dorsal pair are curved, the

convex sides being directed away from each other, so that they are barely discrete at both extremities. Although only this view of the siphuncle was illustrated by Clarke, his illustration is very inaccurate.

Discussion.—*M. bilaterale*, being the only described species of this genus, can be distinguished by the generic characters. Clarke identified the species with *Orthoceras longicameratum* Hall, whose types include an *Anastamoceras* Flower (1939) and at least one species of *Ormoceras*, which will be described and illustrated elsewhere.

Type.—Holotype: New York State Museum no. 12379e/1.

Occurrence.—From the Dalhousie beds of Gaspé, Quebec. Lower Devonian.

ACKNOWLEDGMENT

I wish to acknowledge my indebtedness to Dr. Winifred Goldring of the New York State Museum for permission to section the type of *Metarmenoceras bilaterale*. Dr. C. C. Adams has kindly permitted the photographing of this and other type specimens in the New York State Museum.

ADDENDUM

In the Bibliographic index of Devonian Cephalopoda (Kindle and Miller, 1939), which appeared subsequent to the completion of the above paper, several Actinoceroidea were considered of Devonian age, and a number of species were referred for the first time to *Ormoceras*. Four species of *Armenoceras* from Artic America previously figured and described by Foerste are considered as doubtfully Lower Devonian, and one as definitely Lower Devonian. Nineteen species are placed in *Ormoceras*. *O. Kindlei* Foerste, *O. brevicameratum* Foerste, and *O. novascotium* Foerste are the only species previously placed in that genus, and the only ones for which the published evidence was adequate and correct. Investigations of the writer involving the sectioning of type and supplementary material have made possible the placing of many other species with certainty in modern genera. *Orthoceras longicameratum* Hall and *Orthoceras luxum* are briefly mentioned above. Of the other species, only one can be placed in *Ormoceras* with certainty. This is *Ormoceras vastator* (Hall) of the Schoharie grit, Middle Devonian of New York. A number of the other species have been discussed by the writer (Flower, 1939.) These are properly placed in the Pseudorthoceratidae. Other of the species listed as *Ormoceras* are now in manuscript. Some are definitely referred to genera of the Pseudorthoceratidae, some are of uncertain position pending the study of better material, and a few have been referred to other families.

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JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 5, P. 447, SEPTEMBER, 1940

BLASTOCERINA, NEW NAME FOR BLASTOCERAS FLOWER AND CASTER

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DR. CURT TEICHERT has brought to my attention that *Blastoceras* Flower and Caster (Bull. Am. Paleontology, vol. 22, no. 75, p. 50, 1935) proposed for a genus of Upper Devonian Nautiloidea is preoccupied by *Blastoceras* Fitzinger (1860, Wiss. Naturg. Säugeth., vol. 4, p. 176) used for a genus of Mammalia. The new generic name *Blastocerina* is proposed here to replace *Blastoceras* Flower and Caster, not Fitzinger. The genotype therefore becomes *Blastocerina cylindristoma* (Flower and Caster).

JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 5, PP. 447–450, 7 TEXT FIGS., SEPTEMBER, 1940

AVIAN REMAINS FROM THE PLEISTOCENE OF CENTRAL JAVA

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THE fossil remains of early man found in the Pleistocene beds of central Java have lent such interest to these deposits that material from them in all groups of animals has immediate attraction. In conversation with Dr. G. H. R. von Koenigswald the writer first learned of some bones of birds found in these beds, and recently the specimens have been forwarded to the U. S. National Museum for examination by Dr. W. Holleman, Director of the Mining and Geological Survey, Department of the Netherlands Indies, in Bandoeng, Java.

According to information kindly supplied by Dr. Holleman these remains of birds were obtained from an excavation designated as number 1 near Watoealang, a small village situated on the Solo River about 5 kilometers west of Ngawi, and about 30 kilometers north of Madioen in central Java. The bones were found by a native assistant working under the direction of ir. W. F. F. Oppenoorth, former leader in the geological mapping of Java.

The excavation in question was made in the younger Pleistocene bone-bearing terraces near the river, these deposits being situated unconformably upon the Middle Pleistocene of the Trinil beds, whose vertebrate fauna with its remains of *Pithecanthropus erectus* is so widely known. The river deposits at Watoealang are considered identical with the terraces at Ngandong where the skulls of *Homo soloensis* were found. The birds listed in the following account may, therefore, be supposed to have been contemporaneous with the last-mentioned type of early man.

The writer wishes to express his thanks to Dr. Holleman for the privilege of studying this material, which has given information of importance relative to the occurrence of birds during the Pleistocene. The illustrations in this report have been prepared by Sidney Prentice.

Family CICONIIDAE

LEPTOPTILOS TITAN Wetmore, n. sp.

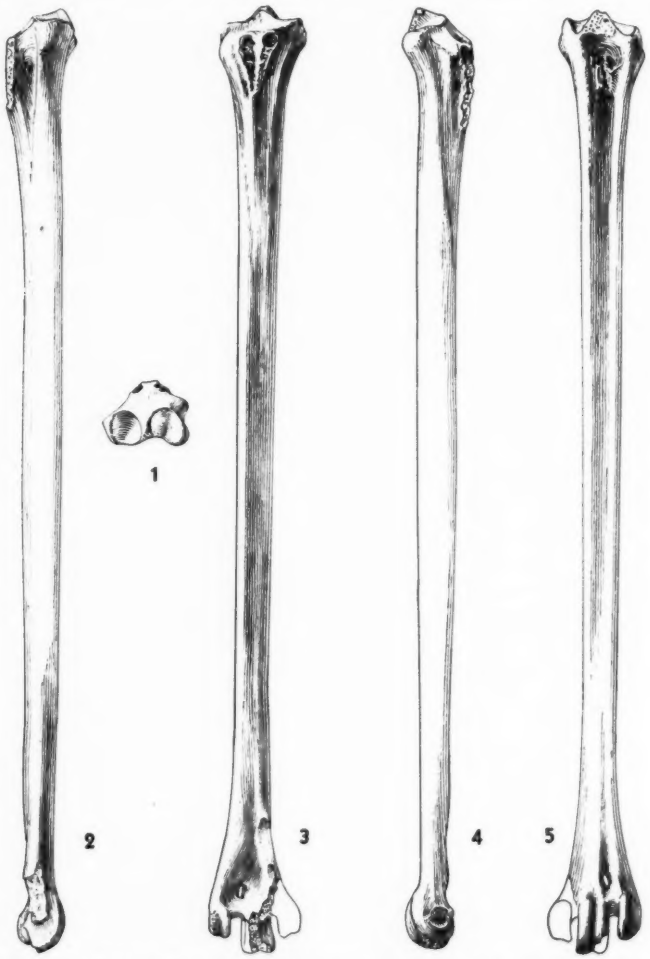
Figures 1–5

Characters.—Tarso-metatarsus (figs. 1–5) similar to that of living *Leptoptilos dubius* (Gmelin)[1] but much longer and heavier; anterior surface less deeply grooved.

Description.—Type, left metatarsus, nearly complete. Mining and Geological Survey, Department of the Netherlands

[1] *Ardea dubia* Gmelin, Syst. Nat., vol. 1, pt. 2, 1789, p. 624 (India).

Indies, cat. no. 3313, from Upper Pleistocene of Watoealang, near the Solo River, central Java. Proximal face of head with the two glenoid facets separated by a high intercondylar tubercle (partly broken away in specimen) with sharply angular sides and roundly truncated point; the outer glenoid facet definitely larger and shallower than the inner; both facets with sharply defined margins that delimit separate open cups, both at nearly the same level; projecting plates of talon mostly broken away and missing, only the base of the groove separating the two remaining, rising from a somewhat elongated and rather narrow base that continues posteriorly as a narrowed ridge to broaden and merge with the body of the shaft; a broad, shallow, posteriorly sloping groove across the rear of the articular surface of the head above the talon; posterior face of shaft with outer side higher than inner, rounded above, becoming very slightly concave for its middle portion, and finally broadened and flattened below; internal face of shaft with a rather deep groove along the base of the talon; the surface below this point gently curved, becoming distinctly narrowed at level of facet for hallux; external face of shaft with a projecting boss at upper posterior margin opposite base of



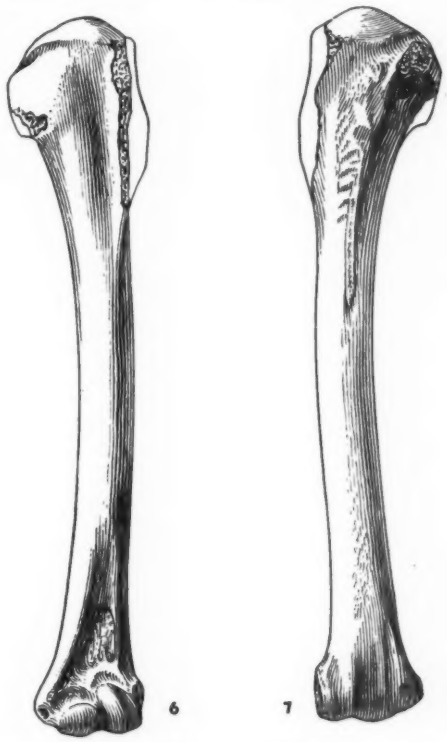
FIGS. 1–5.—*Leptoptilos titan* Wetmore, n. sp. Left metatarsus type, ×¾.

talon, with an elongated, faintly indicated depression anterior to this that slopes off gradually on to the posterior face; below this point the outer surface of the shaft definitely flattened, narrowing gradually below, to be greatly compressed above the outer trochlea; anterior surface with a marked concavity below the head, with two strongly marked tubercles, slightly separated, rising in this depression, while below the groove becomes shallower until a short distance above the lower end the surface is plane for a short distance and then broadened and rounded; a broad, shallow groove at the distal end leading into the inferior foramen, which is relatively small and deeply impressed, located very low, on a line with the inner margin of the outer intertrochlear sulcus; facet for hallux rather long and shallow; posterior face of shaft above trochlea somewhat concave; outer trochlea compressed, rather short, with inner face considerably excavated, its inner anterior margin nearly straight, and a definitely raised point bounding the groove of the adjacent sulcus anteriorly; outer surface of the outer trochlea rounding smoothly to the outer margin, which had a slightly excavated impression (its free external margin partly broken away); middle trochlea partly missing, with anterior face deeply and evenly grooved; inner trochlea missing. Bone brown in color, well preserved.

Measurements.—Total length from point of intercondylar tubercle on proximal end to distal margin of middle trochlea 372 mm.; greatest transverse breadth of head 33.3 mm.; smallest transverse diameter of shaft 12.3 mm. Other pertinent measurements not available because of breakage in specimen.

Remarks.—This species is highly remarkable for its great size as indicated by the length and strength of the metatarsus. Though skeletons of modern *Leptoptilos dubius* and *L. javanicus* are available for comparison, to get a series of comparative measurements it has been necessary to use study skins from which tarsal measurements are readily obtained.

Leptoptilos dubius (5 specimens seen), largest of the marabou storks, has the tarsus from 262 to 329 mm. in length. *L. javanicus* (3 specimens) ranges from 243 to 282 mm., and *L. crumeniferus* (5 specimens) from 225 to 297 mm. Tarsal measurements in the skin are made in the usual way by taking the length from the back of the articulation with the lower end of the tibio-tarsus (this point corresponding roughly with the upper margin of the talon in the bone) to the articulation of the middle toe. Taking this same measurement on the fossil gives a length of approximately 365 mm., or slightly less than the dimension given above for the total length of the fossil bone.



FIGS. 6, 7.—*Grus grus* (Linnaeus). Left humerus, ×5/12, from the late Pleistocene of Watoealang, Java.

The lengths of the tarsus in the three other living storks of large size are as follows: *Xenorhynchus asiaticus* (8 specimens) 303 to 340 mm.; *Ephippiorhynchus sengalensis* (4 specimens) 312 to 360 and *Jabiru mycteria* (8 specimens) 288 to 342 mm.

The tarsus in *Xenorhynchus* is remarkably slender, and in *Ephippiorhynchus* appreciably more so than in *Leptoptilos dubius*. As

L. titan agrees with *L. dubius* there is no indication of alliance between it and the other two species just mentioned. The much greater size of *Leptoptilos titan* is readily evident. It must have been a bird that in life was decidedly larger than the greatest of the living adjutants.

Allocation of the fossil to the genus *Leptoptilos* is made on the form of the ridge leading to the supporting base of the talon, this being narrowed and raised, and on the position of the facet for the articulation of the hallux, which is relatively elevated. In these the extinct bird agrees with *Leptoptilos dubius* and *L. javanicus*. Some of the smaller Ciconiidae have the ridge below the talon narrowed, but in *Jabiru mycteria* it is broad and little elevated. The attachment of the hallux is relatively higher in *Leptoptilos* than in other storks.

Family Accipitridae
Subfamily Aegypiinae

The distal portions of a right ulna, no. 1145, and a right radius, no. 1043, are those of a vulture of this subfamily, being from a species about the size of *Pseudogyps bengalensis*. These are typical in form of birds of this group and apparently represent an extinct species. It is not considered desirable to give them a definite name at this time because of uncertainty as to their exact generic identity and thus of their relation to living forms. They are of interest as indicating the presence of birds of this type in the deposits at Watoealang.

Family Gruidae
Grus grus (Linnaeus)
Figures 6, 7

Ardea grus Linnaeus, *1758*, Syst. Nat., vol. 1, p. 153 (Sweden).

A left humerus, cat. no. 885, from Watoealang, is complete except for the thin margin of the *crista* superior, and a few other projecting points (fig. 6 and 7). In size and form this specimen is identical with the living crane and I have no hesitance in identifying it as that species. In four skeletons of *Grus grus lilfordi* the humerus measures from 219 to 222.5 mm.; while in three *Grus grus grus* it is slightly smaller ranging from 211 to 213 mm. The fossil with a length of 225 mm. is similar to the first mentioned. It is doubtful however that the apparent difference in the humerus between these two living races is valid, as it is not reflected in wing measurements of skins that I have seen.

There are no records of occurrence of the crane in Java, and at the present time it winters south only to the Yangtse Valley, Hainan, Swatow and northern India. Pleistocene conditions apparently carried it much farther south, and the occurrence in central Java is of particular interest in its possible indication of climatic conditions of the period from which it comes.

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HOLOTYPE OF PLESIOSAURUS LONGIROSTRIS BLAKE AND CLASSIFICATION OF THE PLESIOSAURS

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ABSTRACT—The holotype of *Plesiosaurus longirostris* Blake, which has been missing for many years, is refigured and redescribed and is allocated to its proper position in the order. The previous classifications of the plesiosaurs and the characters upon which they were based are discussed. A new grouping of the genera, based upon characters emphasized by Seeley, Williston, and Watson, is proposed.

IN THE Spring of 1931 the Museum of Comparative Zoology secured, by exchange with Tufts College, the skeleton of an unidentified plesiosaur. The identification of the specimen showed it to be the long-lost holotype of *Plesiosaurus longirostris* Blake, which had been described while still in the shop of Mr. Brown-Marshall of Whitby, England.

The specimen was so badly infected with the "alum" or "pyrite disease" that it was necessary to dismantle, thoroughly clean, and disinfect it. It was expertly remounted this past summer by Mr. George Nelson, whose long experience as a taxidermist has given him an appreciation of the form and attitude of animals which is accurately reflected in the beauty of his mounts.

As the work of rehabilitation progressed, it became evident that the fears of Professor Blake (1876) that the specimen was composite, and had been assembled in the shop of Mr. Brown-Marshall were entirely justified. Professor Blake remarked (p. 250) that it "is in a very perfect state of preservation—too perfect, in fact; for as the neck and head have been confessedly put straight, having lain on the fore-paddle, some doubt is entertained (without much reason, however, I think), how far the rest is natural." As it stands today the specimen consists of a badly damaged skull, a connected series of eighty-five vertebrae from the third or fourth cervical to the twenty-second caudal, three humeri, one femur, three fore-paddles, and a paddle which obviously had been assembled.

Both the skull and the vertebral column belong to the genus *Macroplata* (Swinton, 1930); and considering the relative scarcity of the remains of this genus, it is possible that they belong to the same individual. However, it is impossible to be certain for the atlas and axis are missing. Both show the same type of preservation, which at best only indicates that both came from the same locality.

The girdles are represented by a few fragments too poorly preserved to be of any aid in identification.

Because of the uncertainty that the skeleton belongs with the skull Professor Blake insisted (p. 252) that the new species was based on the skull alone. However, I think it is safe to consider the vertebral column as a part of the type, for it is possible or even probable that they belong to the same individual. From the characters of the skull and also of the vertebrae it is no longer possible to retain this species in the genus *Plesiosaurus*, but it must be transferred to *Macroplata*.

DESCRIPTION

MACROPLATA LONGIROSTRIS (Blake)

Plesiosaurus longirostris BLAKE, *1876*, in Tate and Blake, *The Yorkshire Lias*, pp. 250–252, pl. 3, fig. 2; pl. 1, fig. 6.

Plesiosaurus longirostris LYDEKKER, *1889*, *Catalogue of the fossil Reptilia and Amphiba in the British Museum (Nat. Hist.), pt. 2. Ichthyopterygia and Sauropterygia*, pp. 271–273.

"Plesiosaurus" longirostris Watson, *1909*, *Manchester Lit. Philos. Soc., Mem. and Proc.*, vol. 54, no. 4, pp. 3, 21, 22.

Type specimen: No. 1033 in the collection of Fossil Reptiles and Amphibians in the Museum of Comparative Zoology, consisting of a rather badly damaged skull with a continuous series of 85 vertebrae, which may belong to the same individual, and 4 limbs, which may belong to more than one individual.

Horizon and locality: Upper Lias, Zone of *Ammonites serpentinus* Reincke, Whitby, Yorkshire, England. According to William

E. Schevill *Ammonites serpentinus* Reincke —*Hildoceratoides serpentinus* (Reincke) after S. S. Buckman. This zone would then be the Hildoceratan zone of Evans and Stubblefield, which is middle Whitbian. The specimen probably came from near the bottom of the Alum shale.

Skull.—The skull was badly damaged during its preparation by Mr. Brown-Marshall. A section about 3 inches long is mis-

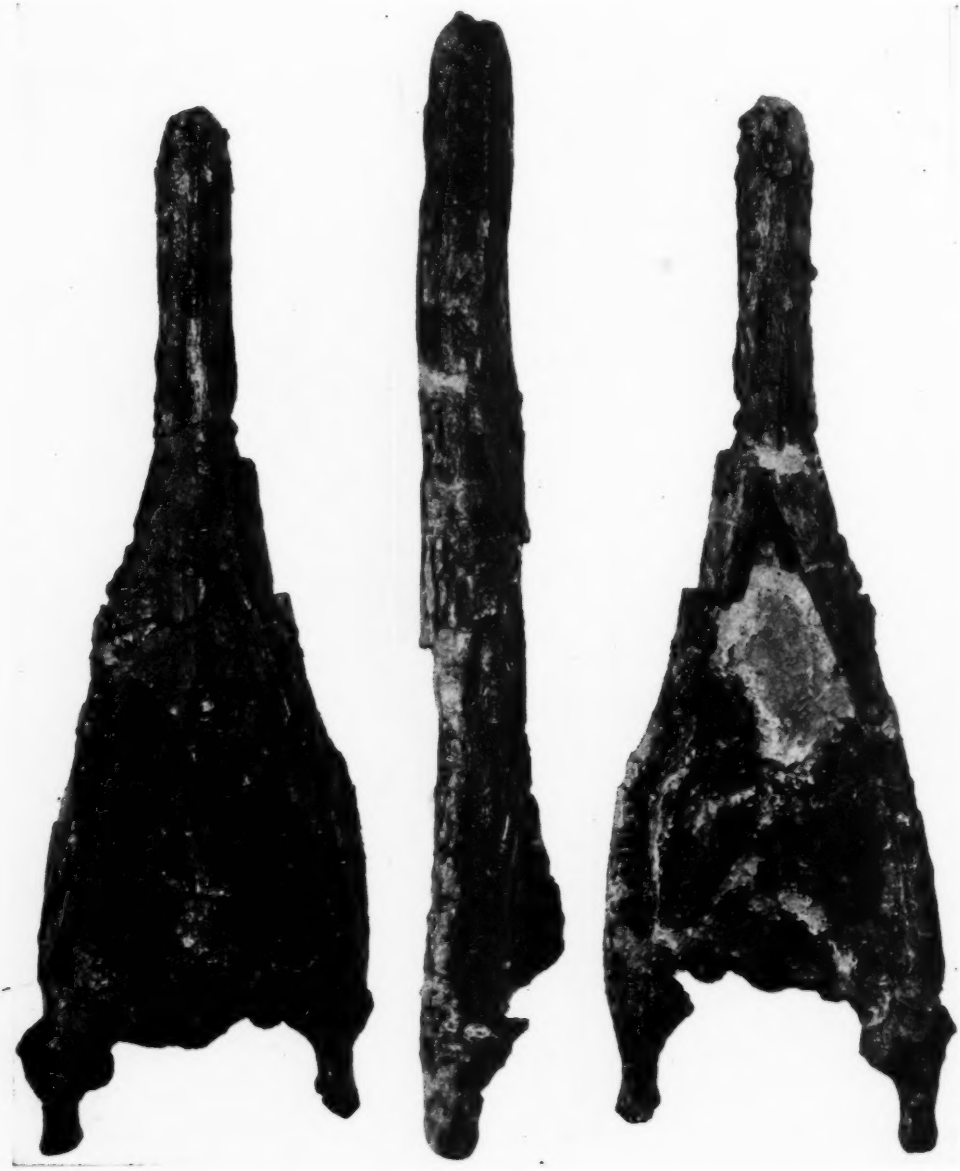


FIG. 1.—*Macroplata longirostris* (Blake). Dorsal, lateral, and ventral views of the skull as it was received at the Museum of Comparative Zoology, dorsal and ventral views approximately $\times\frac{1}{3}$.

sing from the snout just in front of the external nares. The posterior portions of the maxillaries, the jugals, the postorbital bars and adjacent portion of the skull roof, and all of the palate except that attached to the basicranium are missing. Also the coronoid process on both lower jaws has been lost. Parts of the lower tooth series had been substituted for the missing parts of the maxillaries. Fortunately there were good contacts for these fragments in the lower jaws. The missing part of the palate had been "reconstructed" from odd scraps of bone and bits of broken crockery cemented together with putty. The result was then impregnated with black paraffin and given several coats of stove polish. As originally received at the museum the skull was considerably shortened (compare figs. 1 and 2). However, with the exception of the missing coronoid process, the left lower jaw is complete as far forward as the missing part of the snout and gives us the actual length of the postnarial portion of the skull, enough remaining to make a fairly accurate restoration (fig. 2, *A–C*).

The skull is long and narrow, with the rostrum forming a little more than half of the total length. The breadth across the quadrates (265 mm.) is contained in the length (680 mm.) two and one-half times. The height of the skull at the occiput is about one-half the quadrate breadth. The external naris is located 35 mm. posterior to the midlength of the skull and lies about the midlength of a short U-shaped groove, which passes forward and downward from a point near the midline just in front of the orbit. The orbit lies about 50 mm. behind the external naris and was probably circular in outline. It faces more upward than laterally. The supratemporal fenestrae are long and narrow, and the parietal crest is thin but not greatly elevated. Probably the deep adductor mandibuli muscle was quite massive.

The preservation of the skull is such that the maxillo-premaxillary suture is the only one which can be determined with certainty. Consequently the skull will be considered by regions rather than by individual bones.

Rostrum: As stated before the rostrum forms a little more than half of the total length of the skull. The width at the anterior end of the rostrum is about three-fourths of that just in front of the external nares. Along the dorsal surface is a prominent ridge, which is thin and sharp at either end and rather broad in the middle. On the buccal surface of the rostrum is a low, broad ridge, which projects downward beyond the base of the teeth. There is a similar structure in most phytosaurs, concerning which Professor E. C. Case orally expressed the opinion that it protected the gums from the force of the bite.

The maxillo-premaxillary suture starts on the side of the rostrum at the tenth tooth and passes inward and backward along the medial side of the external naris to a point opposite the middle of the orbit. The preservation of the bone at this point is too poor to determine what the relationships are.

Orbito-nasal region: The skull begins to broaden just in front of the external nares. The preserved part of the lateral surface of the skull is nearly straight. If projected posteriorly, the line would meet the part of the squamosal preserved. Consequently the side must have been nearly straight. In this region that part of the maxillary above the teeth is produced into a rather prominent ridge. Posteriorly it disappears at a point about opposite the middle of the orbit. Its anterior extent is not known, but presumably it continues onto the rostrum and disappears about opposite the tenth tooth.

The anterior half of the left orbit is preserved. Judging by this part the orbit was circular in outline, and was probably about 50 mm. in diameter. The dorsal and anterior edges are produced into a prominent ridge which disappears near the lower border of the orbit.

The posterior end of the maxillary is missing, but judging by the length of the lower tooth row the maxillary probably extended a short way posterior to the orbit.

The external naris is elliptical in outline, about 20 mm. long and 12 mm. wide. It lies about 50 mm. in front of the orbit near the midlength of a broad, shallow groove. It seems reasonable to assume that this groove housed a fleshy mechanism for closing the nostril when the animal submerged.

Skull roof and quadrate: The parietal crest is thin, sharp, and relatively high but does not project much above the general

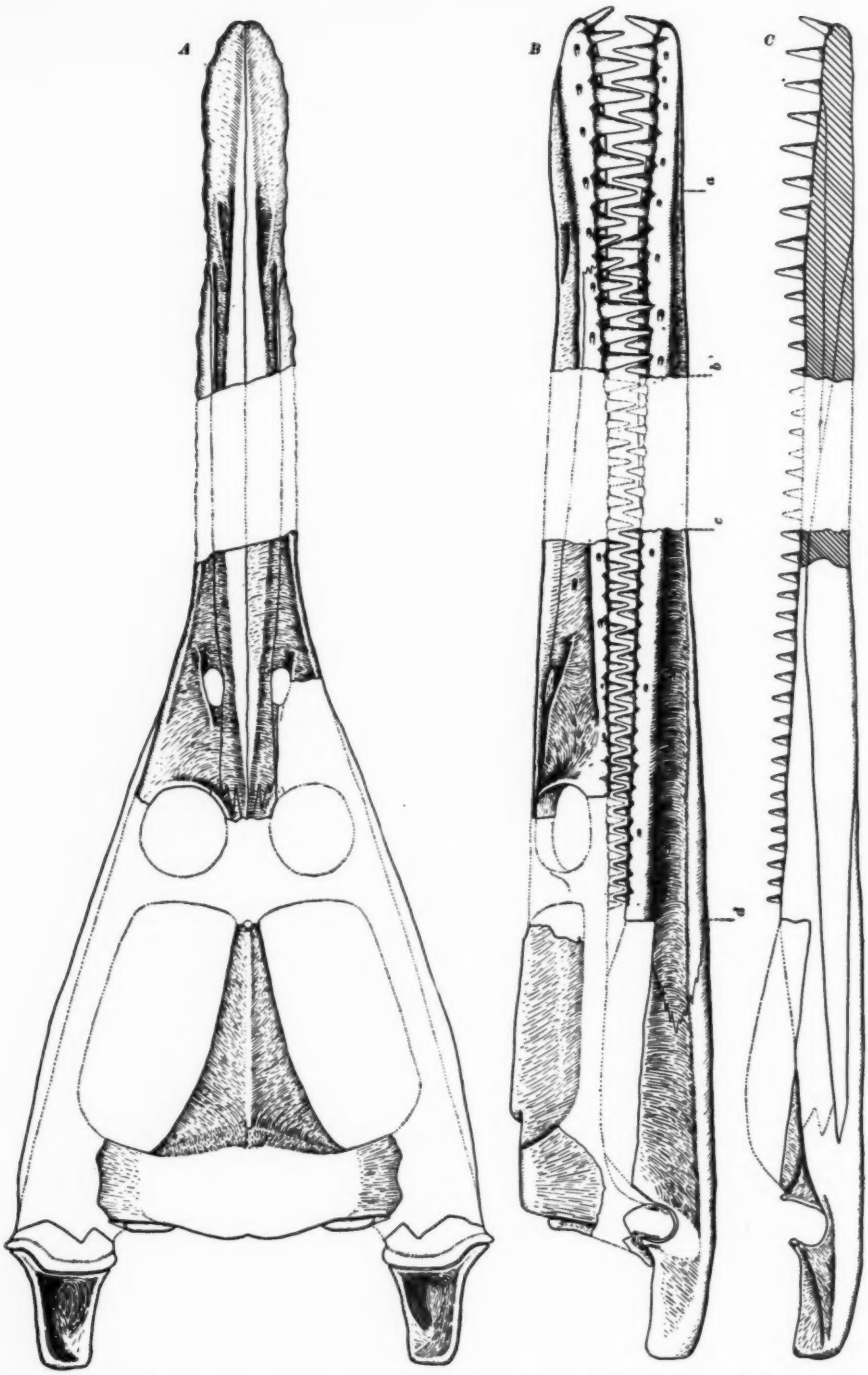


FIG. 2.—*Macroplata longirostris* (Blake). Views of skull ×¼. *A*, Dorsal view. *B*, Left side (reversed); *a*, *b*, *c*, and *d*, location of sections shown in figs. 3*a*–*d*. *C*, Medial aspect of left lower jaw.

level of the skull roof. It has a somewhat greater anteroposterior extent than in most long-snouted plesiosaurs. At the anterior end of the part preserved is an emargination which may represent the pineal foramen.

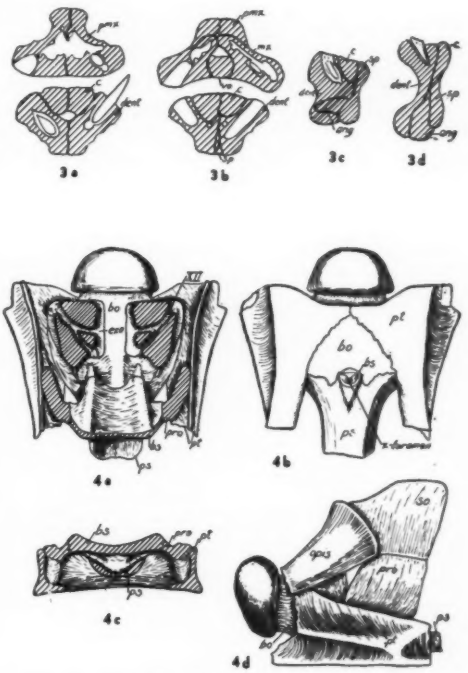
The part of the skull roof behind the parietal crest is broad and flat and without any distinctive features. The preservation is so poor that it is impossible to determine the limits of the parietals and squamosals. Anteriorly the skull roof passes smoothly into the parietal crest. Posteriorly it thins to a rather sharp edge. On the ventral surface is a rather high, sharp median ridge, which extends forward nearly to the supraoccipital. The union of the skull roof with the dorsal end of the quadrate is not at all clear, due to infiltration of pyrite. The lower end of the quadrate does not present any features particularly different from other plesiosaurs.

The basicranium escaped the severe infiltration of pyrite which affected other parts of the skull. Some details are obscured by pyrite, but on the whole the preservation is very good. The principal damage suffered was during its first preparation.

The general configuration of the braincase and the position of the pineal indicate that the brain was considerably elongated.

On the ventral side of the braincase just behind the parasphenoid is a pit lying between the basioccipital and the basisphenoid. From the anterior side of this pit is a small foramen (x-foramen) which enters the basisphenoid. Its exit has not been discovered. A similar foramen is found in *Kronosaurus* (White, 1935), and in *Trinacromerum* (Williston, 1908, fig. 1). The function of this foramen is not altogether certain. It may represent the exit of the palatine artery and nerve. They might have been forced into the substance of the basisphenoid by the posterior migration of the attachment of the pterygoids to the basicranium. I do not believe that it is the entrance of the internal carotids; but if so, this opening is not homologous with that in *Kronosaurus*, because in the latter the internal carotids enter between the basioccipital and the pterygoids (White, 1935, p. 221).

The basioccipital (fig. 4*a–d*) forms the whole of the hemispherical condyle. The notochordal pit is a little above the center. On the dorsal side of the basicranium the basioccipital is exposed as a narrow strip of bone, which extends forward a little beyond the foramen mentioned above. On the ventral side, the basioccipital is exposed in a triangular area with the apex directed posteriorly. This area is bounded anteriorly by the parasphenoid and laterally by the pterygoids.



FIGS. 3, 4.—*Macroplata longirostris* (Blake). *3*, Sections of rostrum and lower jaw as indicated in fig. 2*B*, ×¼. *4*, Basicranium; *a*, dorsal, *b*, ventral, *c*, anterior, and *d*, lateral views, ×¼.

The tubera basioccipitalia are partially concealed by the underlap of the pterygoids. As near as could be determined (they could not be exposed in their entirety for fear of damaging the specimen) they are simple rugose protuberances on the posterior lateral angles of the basioccipital, and are made up entirely of that bone.

The basisphenoid and parasphenoid are broken through the hypophyseal fontanelle. The part preserved is a little shorter than the basioccipital. Its dorsal surface was apparently finished in cartilage, as the bone

does not have a good surface. At the anterior end the dorsum sellae is broken away, and the basisphenoid drops abruptly to the parasphenoid. The nature of the bone makes it impossible to determine the presence or absence of a suture between them at this point. On either side between the parasphenoid and basisphenoid parts is a deep groove, which was probably traversed by the internal carotid. Ventrally the basisphenoid is exposed only as the anterior rim of the x-foramen.

The parasphenoid appears as a trough-shaped bone underlying the anterior part of the braincase. Posteriorly it unites with the basisphenoid, the basioccipital, and the pterygoids (fig. 4*a*–*b*). Above the pterygoids it sends a prong backward on either side of the braincase, which articulates with the basioccipital laterally and the exoccipital dorsally. The posterior limit of this prong cannot be determined.

The proötic is united with the basisphenoid just behind the dorsum sellae. From this point it curves outward and backward and unites posteriorly with the paroccipital. The ventral border is in contact laterally with the pterygoid. The preservation of the specimen makes it impossible to determine whether this union is sutural or not. Dorsally it unites with the supraoccipital.

The supraoccipital unites ventrally with the proötic and ventro-posteriorly with the paroccipital. It forms the superior border of the foramen magnum and the upper half of the lateral. The lateral borders of the foramen slope upward and forward from its inferior border. It is impossible in this specimen to tell whether or not the supraoccipital is paired, as in *Peloneustes* and *Trinacromerum*.

The paroccipital (exoccipital and opisthotic) extends upward from the basioccipital to the supraoccipital. The lower end is expanded and extends down on the sides of the basioccipital to the tubera basioccipitalia. Just above the floor of the braincase the twelfth nerve leaves by two foramina. These nerve roots unite near the middle of the bone and leave through a single foramen (fig. 4*a*). This is beautifully shown on both sides by a fortuitous break through the exoccipitals at this point.

The upper end is expanded into the opisthotic part and unites with the supraoccipital. The outer two-thirds of the paroccipital process is broken away. The part remaining is elliptical in cross section. The long axis of the ellipse measures 12 mm., and the short axis 6 mm. Because of the poor preservation nothing of the semicircular canals could be determined.

The pterygoids are L-shaped in cross section. The lower leg of the L meets its fellow in the midline just in front of the occipital condyle and beneath the basioccipital (fig. 4*b*). In front of this point the pterygoids diverge rapidly so that a large triangular area of the basioccipital is exposed. Anteriorly the descending process of the proötic is enclosed between the two legs of the L. On the lateral surface and at about the middle of the height of the upper leg of the L is a prominent ridge, which extends posteriorly from a point opposite the midlength of the proötic. In their general features the pterygoids agree very well with those described for *Kronosaurus* (White, 1935) and *Brachauchenius* (Williston, 1906). The details, however, are quite different.

An epipterygoid has not been found.

Lower jaw.—The preservation of the lower jaw is a little better than that of the skull. Most of the bones can be determined with more or less certainty. As is the case with most plesiosaurs, there is a great deal of overlap in the sutures.

The lower jaw is long and slender, with the symphysis making up a little less than one-half of the total length. Posterior to the symphysis the dorsal and ventral parts of each ramus are expanded, but the central part is rather thin (fig. 3*c*, *d*). Structurally this gave the jaw the greatest strength with the minimum of material and better equipped the jaw to resist a side wrench when active prey was seized.

Angular and articular: The angular and articular have fused so that it is impossible to identify them as separate units. The angular extends forward on the ventromedial side of the lower jaw nearly to the symphysis.

The retroarticular process is long and strong. It extends posterior to the quadrate fossa a distance equal to a little more than

the width of the fossa. The process is triangular in cross section, the long side being ventrolateral. The dorsolateral and dorsomedial edges are produced into high, thin ridges, with a deep triangular pit between. The apex of the pit is directed posteriorly. The posterior end of the retroarticular process is very rugose for the insertion of the retractor mandibuli muscle.

Surangular and prearticular: The presence or absence of these bones cannot be determined.

Splenial: The splenial is a broad, thin plate of bone on the medial side of the lower jaw. It extends from a point a short distance anterior to the quadrate fossa to about the midlength of the mandibular symphysis. Its greatest vertical depth is near the midlength of the lower jaw.

Coronoid: The toothless coronoid has a somewhat greater anteroposterior extent than the splenial. Though its posterior limit cannot be determined, that part of the coronoid which takes part in the symphysis is heavier and more robust than the posterior part. Since a part of the snout is missing, it is impossible to determine whether there are one or two coronoids.

Dentary: The dentary is the only tooth-bearing bone in the lower jaw. It extends only a short distance posterior to the tooth row. At the anterior end of the symphysis the two dentaries are fused. A similar condition is found in most members of the Pliosauridae.

Teeth: The relative size and distribution of the teeth are similar to those in the Pliosauridae, and as in that group the enamel of the teeth is marked by vertical ridges. Anterior to the maxillo-premaxillary suture the snout carries large laniary teeth. Those in the immediate vicinity of the maxillo-premaxillary suture are quite small. The three or four teeth behind this suture are as large as those in the front of the snout. In the front part of the lower jaw the teeth are as large as those in the upper. Opposite the maxillo-premaxillary suture there is an abrupt change to the size normal for the rest of the jaw.

Vertebral column.—There are 85 vertebrae in a connected series of which 30 are cervical, 4 or 5 pectoral, 22 or 24 dorsal, 3 or 4 sacral, and 22 caudal. Unfortunately the vertebrae transitional from cervicals to pectorals and from dorsals to sacrals are so badly damaged that it is difficult to be certain of the exact number in each category. The atlas and axis, perhaps one or two anterior cervicals, and a few of the terminal caudal vertebrae are missing. The spines had been broken off all the vertebrae, but were not lost. It was possible to find a few good contacts, and the remainder were placed upon appropriate vertebrae.

Cervical vertebrae: The centra of the anterior cervical vertebrae are small, subcircular in cross section, and three-fifths as long as high. Midcervicals show the greatest length relative to the height of any of the series. On the ventral side of each vertebra is a pronounced haemal ridge between two oval depressions. Near the anterior end of each depression and next to the haemal ridge is a large nutrient foramen. In the posterior cervicals the depression is open laterally (fig. 5).

The zygapophyses of the cervical vertebrae are narrow, the width equaling one-half that of the centrum. The articular faces are nearly horizontal.

In the anterior vertebrae the cervical ribs are fused to the centra. This is probably true for all except the last few, but because of the damage done by the "pyrite disease" it is impossible to be certain. The basal part of each rib is perforated by the vertebral artery. The distal part of each rib has been broken off and lost.

Pectoral vertebrae: In nearly all of their features the pectoral vertebrae are transitional between the cervicals and the dorsals. The haemal ridge is very broad, its width equal to about twice that of the posterior cervicals. The postzygapophyses of these, of the posterior cervicals, and of the anterior dorsals extend beyond the posterior border of the centrum and overlap the centrum of the succeeding vertebra. The diapophyses are borne by both the centrum and the neural arch.

Dorsal vertebrae: The centra of the dorsal vertebrae are rather deeply constricted on the sides. The width at the midlength is only a little more than one-half that at either end. The length remains nearly constant throughout the series from the cervicals to the sacrals. They present the greatest

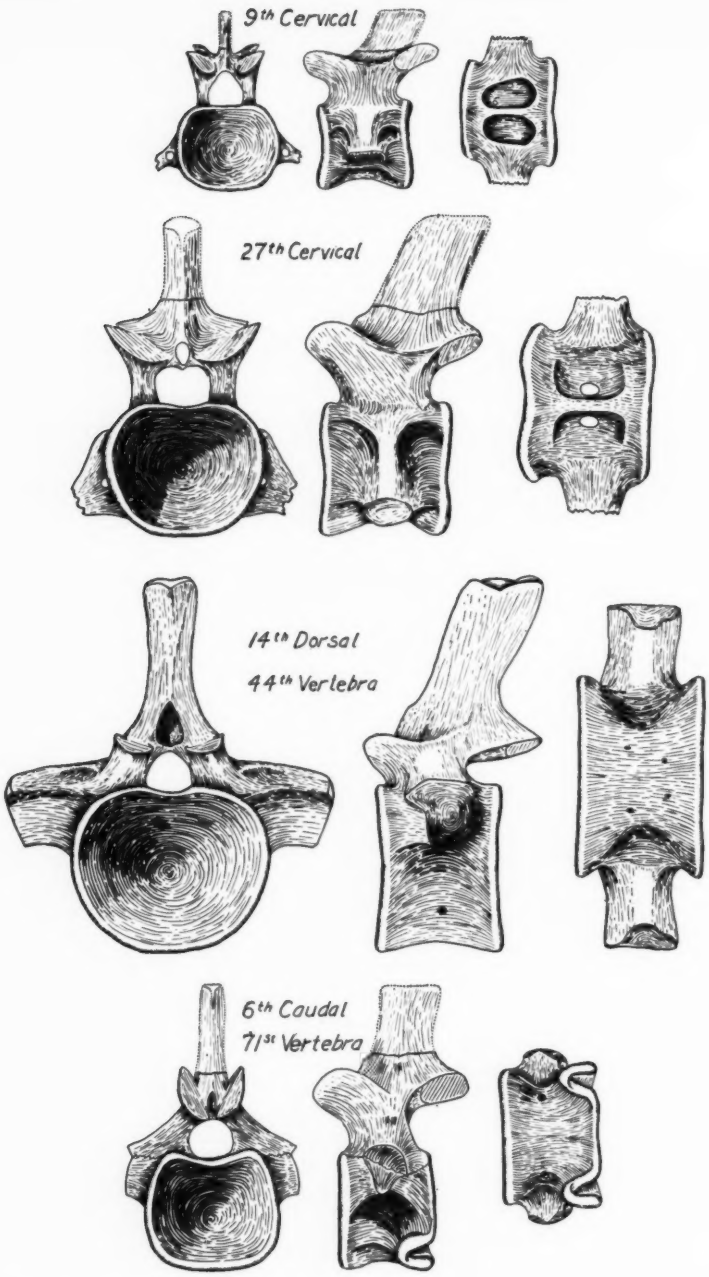


FIG. 5.—*Macroplata longirostris* (Blake). Anterior, lateral, and ventral views of characteristic vertebrae, $\times\frac{1}{3}$.

width and height of any of the vertebrae.

The zygapophyses are proportionately as narrow as those of the cervical vertebrae. The articular faces are nearly horizontal.

The diapophyses are borne entirely by the neural arch and are rather long and strong. The width across the diapophyses is a little more than one and one-half times the diameter of the centrum at the end.

In those vertebrae in which the base of the spine is preserved, there is evidence that in the anterior and middorsals the spine was inclined backwards. In the posterior dorsals and remaining vertebrae the spine is nearly vertical.

Sacral vertebrae: The centra of the sacral vertebrae are somewhat shorter than in the dorsals and are not as deeply constricted laterally. The zygapophyses are intermediate between the nearly horizontal ones of the dorsal series and the very steep ones of the caudals. The diapophyses are made up of both the centrum and the neural arch.

Caudal vertebrae: The anterior caudals resemble the sacrals very closely. The centra are slightly constricted laterally. In those vertebrae which bear chevrons the constriction is divided by a ridge which extends between the articulations of the chevrons for the length of the vertebra. The anterior articulation is small and indistinct, but the posterior is large and prominent (fig. 5). The chevrons begin with the fourth or fifth vertebra. The damage done by the "pyrite disease" makes it impossible to be certain.

ON THE CLASSIFICATION OF THE PLESIOSAURS

In order to place the above mentioned specimen in the proper genus, I have reviewed the literature which treats of more or less complete skeletons, of which many are known, principally from the Jurassic. The diversity of form in this group, particularly in the pectoral girdle and the length of the neck, indicates that they had undergone a rather lengthy evolution by the time we first know anything about them, i.e. at the beginning of the Jurassic.

Pistosaurus, from the middle Triassic of Germany, is provisionally referred to the plesiosaurs. As is true of many groups, the plesiosaurs burst upon us well advanced in their radiation and we know nothing of their early history. All but one of the families (Polycotylidae) were in existence by the Oxfordian.

In 1892 Seeley divided the plesiosaurs into the Dicranopleura and Cercidopleura on the basis of double- or single-headed cervical ribs. He further subdivided the Dicranopleura into the Brachydeira and Dolichodeira on the length of the neck. In 1903 Williston expressed doubts concerning the validity of these characters for defining major groups. In 1907 he expressed the opinion that the single- or double-headed cervical ribs could not be of more than generic value. Seeley (1892) and Williston (1907) suggested that this character was probably correlated with the geologic age or evolutionary status of the specimen. In the light of the more recent study of reptilian osteology it seems highly probable that in some families the single- or double-headed cervical rib is not a systematic character but rather an indication of the age of the specimen, such as Professor Romer tells me he finds in some pelycosaurs. In any but a very old individual, the vertebral artery might easily pass through a cartilage plug between the rib and vertebra without leaving a mark on either. Except in the case of the large *Rhomaleosaurus*, the difference between a single- and a double-headed cervical rib is too slight to be of any great systematic value.

In none of the systems of classification yet proposed does the length of the neck substantiate the other criteria used. Since the plesiosaurs have gone so far in their evolution before we know anything about them, it seems entirely possible that short-necked and long-necked forms might have appeared independently several times.

The characters of the vertebral centra are emphasized differently by different authors, and there is not sufficient material at my disposal to allow me to make any statement regarding their diagnostic value.

The skull is unknown in many forms and therefore cannot be used as a basis for major divisions. Dolichocephaly has appeared independently at least three times in the suborder. However, other characters of the skull seem to be useful in showing relationships.

The differences in the pelvic girdle are

too small to be useful in defining major groups. The same is true of the limbs.

Seeley (1874 and 1892), Williston (1906) and Watson (1909 and 1911) have stressed the importance of the pectoral arch in the classification of the plesiosaurs. This part of the skeleton, though very conservative in most large groups of reptiles, shows great variation in the form of the arch as a whole as well as in the size and shape of the component bones. However, the pectoral arch does not seem to have lent itself to hit-or-miss variation but shows a tendency to reduce the arch to two pairs of elements—the scapulae and the coracoids. This has been accomplished in three groups—the *Muraenosauridae*, the *Pliosauridae* and the *Elasmosauridae*. As the pectoral girdle presents no real duplication of pattern, it seems to me to present the best basis for classification.

On the basis of the shoulder girdle the Plesiosauria are readily divisible into nine coherent groups which, I believe, are entitled to the taxonomic rank of family. Within each family there is sufficient difference in the pectoral girdle to distinguish the genera readily. The characters of the pectoral girdle which differentiate the families are rather difficult to describe and are best appreciated by an examination of the accompanying figures. I have attempted to express the more obvious characters in an artificial key.

Key to the Plesiosauria

A. Posterolateral angles of coracoids produced: width across posterior ends of coracoids nearly twice the interglenoid breadth.
  a. Clavicles and interclavicle present and well developed, interclavicle enclosing a foramen. . . . Polycotylidae, Williston, 1908. (*Polycotyus, Trinacromerum, Polyptychodon.*)
  a′. Clavicles absent or small; interclavicle present but undergoing reduction in the group (absent in *Colymbosaurus*). . . . Muraenosauridae, n. fam. (*Muraenosaurus, Picrocleidus, Tricleidus, Colymbosaurus.*)
  a″. Clavicles large and well developed; interclavicle absent or small. . . . Cryptocleididae, Williston, 1925. (*Cryptocleidus, Microcleidus, Apractocleidus, Mauisaurus.*)

B. Postero-lateral angles of coracoids not produced; width across posterior ends of coracoids usually less than interglenoid breadth.
  a. Clavicles and interclavicles present and well developed.
    b. Scapulae not meeting coracoids medial to scapulo-coracoid fenestra.
      c. Interclavicle with posterior process. . . . Plesiosauridae, Gray, 1825. (*Plesiosaurus, Sthenarosaurus, Macroplata.*)
      c′. Interclavicle without posterior process or, if present, secondarily developed and enclosing a foramen. . . . Leptocleididae, n. fam. (*Leptocleidus, Eurycleidus, Rhomaleosaurus.*)
    b′. Scapulae meeting coracoids medial to scapulo-coracoid fenestra.
      c. Interclavicle with distinct posterior process. . . . Brancasauridae, n. fam. (*Brancasaurus, Thaumatosaurus, Seeleyosaurus*, n. gen.)
      c′. Interclavicle without posterior process and enclosing a foramen. . . . Tremamesacleididae, n. fam. (*Tremamesacleis*, n. gen.)
  a′. Clavicles absent, interclavicle usually absent (present in *Peloneustes*).
    b. Scapulo-coracoid fenestrae separated by a distance equal to twice the diameter of one fenestra. . . . Pliosauridae, Seeley, 1874. (*Pliosaurus, Peloneustes, Eretmosaurus, Kronosaurus, Brachauchenius.*)
    b′. Scapulo-coracoid fenestrae separated by a distance not exceeding the diameter of one fenestra. . . . Elasmosauridae, Cope, 1869. (*Elasmosaurus, Cimoliosaurus, Simolestes.*)

Plesiosauridae, Gray, 1825
Figures 6*a–f*

Brachycephalic to dolicocephalic; 23 to 38 cervical vertebrae, 20 to 28 dorsals, 2 to 4 sacrals, 30 ± caudals; cervical ribs single- or double-headed or fused to the centra; pectoral girdle usually with the full complement of bones; scapula and coracoid not meeting medial to scapulo-coracoid fe-

nestra; posterolateral angles of coracoids not produced.

Included genera: *Plesiosaurus*, *Sthenarosaurus* and *Macroplata*.

It is apparent from the characterization that this family is in great need of revision. However it must be done by someone who has access to the specimens, because the early illustrations, though beautiful to look at, are vague in regard to details. The genus *Plesiosaurus* has been and still is the wastebasket into which all unidentifiable scrap is dumped, usually with a new specific name. However, *Plesiosaurus*, as shown by *P. dolichodeirus*, is the most generalized of the plesiosaurian genera and is one from which most of the others could be derived.

CRYPTOCLEIDIDAE Williston, 1925
Figures 7*a–d*

Brachycephalic; 29 to 40 cervical vertebrae, 22 to 26 dorsals, 3 to 4 sacrals, 30 ± caudals; cervical ribs single-headed; posterolateral angles of coracoids produced; interclavicle absent or reduced to a slender splint of bone; clavicles meeting in midline; scapula and coracoid meeting medial to scapulo-coracoid fenestra and forming a narrow bar between the two fenestrae.

Included genera: *Cryptocleidus*, *Microcleidus*, *Apractocleidus* and *Mauisaurus*.

The characters of the shoulder girdle of this family serve to set it off sharply from the others. It might be argued that this and the next family should be considered as subfamilies; but as they have obviously enjoyed a separate evolution for a long time (we do not know a common ancestor), it is better that they remain separate.

MURAENOSAURIDAE White, n. fam.
Figures 8*a–d*

Brachycephalic; 28 to 44 cervical vertebrae, 22 to 25 dorsals, 3 to 4 sacrals, 30 ± caudals; cervical ribs single-headed; posterolateral angles of coracoids produced; clavicles absent or reduced to narrow rods of bone; interclavicle undergoing reduction in the family (absent in *Colymbosaurus*); scapula meeting coracoid medial to scapulo-coracoid fenestra, and the two forming a narrow bar between the fenestrae.

Included genera: *Muraenosaurus*, *Picrocleidus*, *Tricleidus*, *Colymbosaurus*.

This family like the above is sharply set off from the others by the characters of the shoulder girdle.

BRANCASAURIDAE White, n. fam.
Figures 9*a–c*

Brachycephalic; 27 to 37 cervical vertebrae, 19 to 22 dorsal, 2 to 3 sacral, and 25 to 43 caudal; cervical ribs single- or double-headed; clavicles and interclavicle present and well developed; interclavicle with posterior process; scapula meeting coracoid medial to scapulo-coracoid fenestra; fenestra small and with a broad bar between; one or two openings in the girdle anterior to scapulo-coracoid fenestrae.

Included genera: *Brancasaurus*, *Thaumatosaurus*, *Seeleyosaurus*, n. gen.

Wegner was not certain that he had restored the pectoral girdle of *Brancasaurus* correctly. By outlining the bone in his photograph of the girdle and reversing it upon itself it is seen that his restoration is entirely within the limits of plausibility.

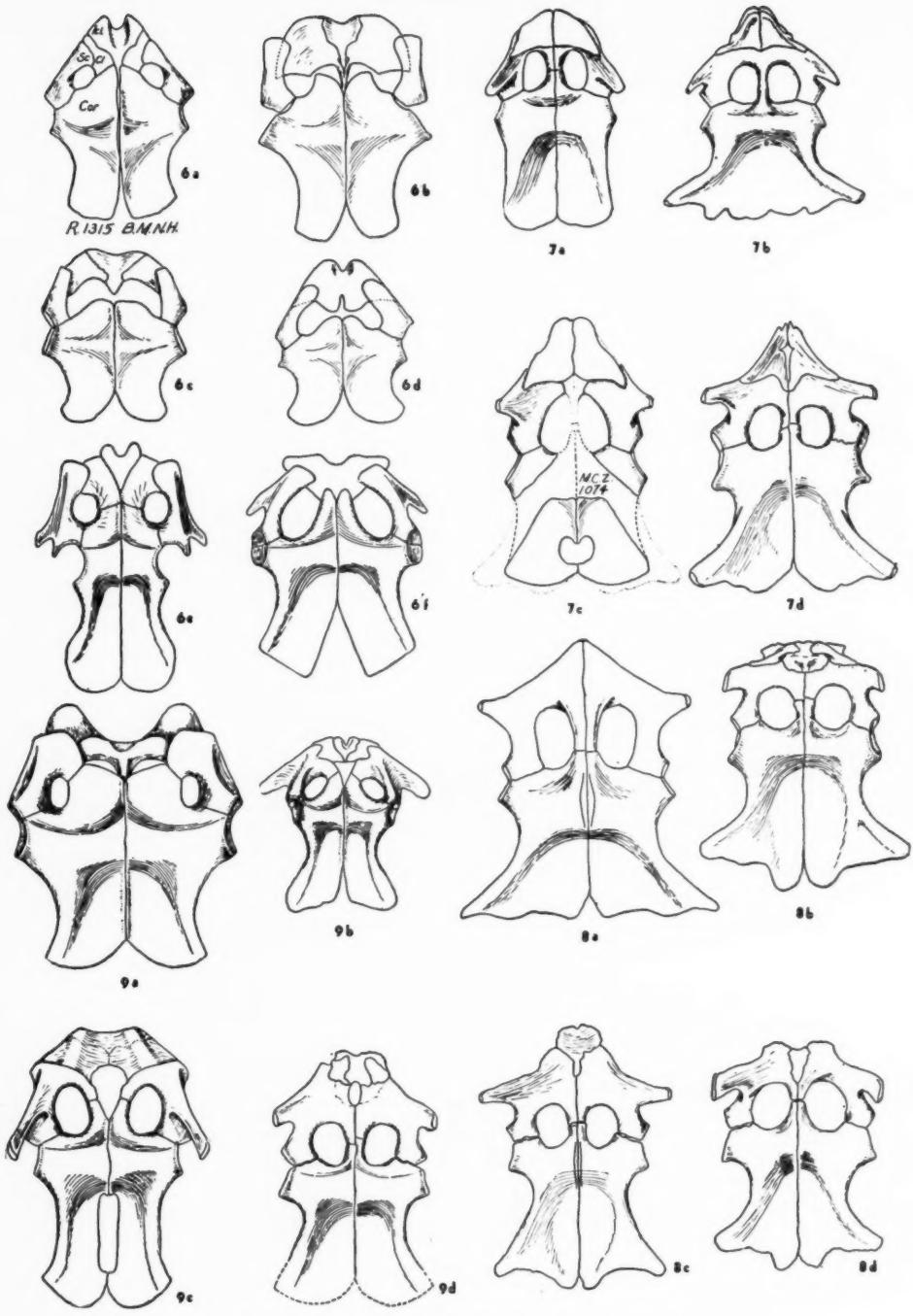
This family seems to be related to the following. The reduction of the posterior process of the interclavicle is the principal change necessary to produce the *Tremamesacleididae* from this family.

The specimen which E. Fraas (1910) referred to *Plesiosaurus guilelmi imperatoris* Dames differs from the type in that it possesses an interclavicle and that the scapula and coracoids meet medial to the scapulo-coracoid fenestra, the skull is relatively much shorter for its width. Dames (1895) and Watson (1911) state that the type did not possess an interclavicle. The character of the shoulder girdle places the specimen described by Fraas in the *Brancasauridae*, but the type of *Palesiosaurus guilelmi imperatoris* belongs in the *Plesiosauridae*, s. l. Since neither of the two genera of the *Brancasauridae* can receive this form, it is necessary to give it a separate designation; and I take great pleasure in naming the genus after the late Professor H. G. Seeley, who laid the foundation for our understanding of the Plesiosauria.

SEELEYOSAURUS White, n. gen.

Genotype, *S. holzmadenensis* White, n. sp.

Generic diagnosis: Skull brachycephalic; teeth long and slender; orbits anterior to



FIGS. 6–9.—For explanation see opposite page.

midlength of skull; 35 cervical, 20 dorsal, 2 sacral, 43 caudal vertebrae; cervical ribs double-headed; neural spines high and broad; anteroposterior length of shoulder girdle nearly twice interglenoid breadth; clavicles and interclavicle present and well developed; interclavicle with distinct posterior process; scapula and coracoid meeting medial to scapula-coracoid fenestra.

SEELEYOSAURUS HOLZMADENENSIS
White, n. sp.
Figure 9*b*

Holotype: The specimen in the Stuttgart Museum described by E. Fraas in *Palaeontographica*, vol. 57, pp. 107–123, pls. 6, 7 and pl. 10, fig. 6, text figs. 1–6, and referred by him to *Plesiosaurus guilelmi imperatoris* Dames.

Horizon and locality: Upper Lias, Holzmaden, Germany.

Specific diagnosis: Same as generic.

Discussion: The extremely brachycephalic skull, the presence of an interclavicle, and the general form of the shoulder girdle show that this specimen cannot belong to the species to which Fraas assigned it.

TREMAMESACLEIDIDAE White, n. fam.
Figure 9*d*

Brachycephalic; 38 cervical vertebrae, 21 dorsal, 14 ± caudal; cervical ribs single-headed; clavicles and interclavicle present and well developed; interclavicle enclosing a foramen; scapula meeting coracoid medial to scapulo-coracoid fenestra and forming a narrow bar between the fenestrae.

Included genus: *Tremamesacleis* Withe, n. gen.

The species *platycleis* and *durobrivensis* have been assigned to *Muraenosaurus*, but the interclavicles differ radically from *M. leedsi*, the type species of *Muraenosaurus*. In the latter species the clavicles are absent, and the interclavicle possesses a short but distinct posterior process. The other two species possess clavicles and an interclavicular foramen, and the posterior process of the interclavicle is absent. As the two species in question do not readily fall into any of the known genera, it is necessary to erect a new genus for them.

TREMAMESACLEIS White, n. gen.

Genotype species, *Muraenosaurus platycleis* Seeley, *1892*, Roy. Soc. London, Proc., vol. 51, pp. 139–141, fig. 6.

Referred species: *Muraenosaurus durobrivensis* Lydekker 1889, Cat. Foss. Rept. and Amphib. Brit. Mus. (N. H.), p. 8. Andrews (1910) says that the type of this species is a young individual, but he thinks that the species is valid.

Diagnosis: Skull brachycephalic; teeth conical and of medium length; orbits anterior to midlength of skull; 38 cervical, 21 dorsal, and 14+ caudal vertebrae; cervical ribs single-headed; clavicles and in

EXPLANATION OF FIGURES 6–9

FIG. 6.—Plesiosauridae; ventral aspect of pectoral girdles. *a*, Specimen in British Mus. identified by Andrews (1910) as *Plesiosaurus rostratus* Owen and as *P. dolichodeirus* Conybeare by Watson (1924) ×1/12. *b*, *Plesiosaurus macrocephalus* Owen, ×1/9, after Watson (1911). *d*, *Sthenarosaurus dawkinsi* Watson, ×1/24, after Watson (1909). *d*, *Plesiosaurus conybeari* Sollas, ×1/24, after Sollas (1881). *e*, *Plesiosaurus laticeps*, Owen, ×1/15, after Woodward (1932). *f*, *Plesiosaurus hawkinsi* Owen, ×1/12, after Lydekker (1889).

7.—Cryptocleididae; dorsal aspect of pectoral girdles. *a*, *Microcleidus homalospondylus* (Owen) ×1/18, after Watson (1909). *b*, *Apractocleidus teretipes* Smellie, ×1/20, after Smellie (1916). *c*, *Mauisaurus haasti* Hector, immature, ×1/18, the broken lines indicate the missing parts, and the dotted lines indicate the probable limits of an adult form, Mus. Comp. Zool. no. 1074. *d*, *Cryptocleidus oxoniensis* Phillips, ×1/18, after Andrews (1910).

8.—Muraenosauridae; dorsal aspect of pectoral girdles. *a*. *Colymbosaurus megadeirus* Seeley, ×1/20 redrawn from Seeley (1874), *b*, *Tricleidus seeleyi* Andrews, ×1/15, after Andrews (1910). *c*, *Muraenosaurus leedsi* Seeley, ×1/18, after Andrews (1910). *d*, *Picrocleidus beloclis* Seeley, ×1/12, after Andrews (1910).

9.—Brancasauridae and Tremamesacleididae; dorsal aspect of pectoral girdles. *a*, *Thaumatosaurus victor* Fraas, ×1/15, ventral aspect, redrawn from Fraas (1910). *b*, *Seelyosaurus holzmadenensis* White, n. gen., n. sp., ×1/18, ventral aspect, after Fraas (1910). *c*, *Brancasaurus brancai* Wegner, ×1/12, dorsal aspect, restored from Wegner (1914), *d*, *Tremamesacleis platycleis* (Seeley), ×1/24, dorsal aspects, after Andrews (1910).

terclavicle present and well developed; interclavicular foramen present, bounded anteriorly and probably laterally by the interclavicle (Andrews, 1910, pl. 6, fig. 3, indicates that the posterior extent of the clavicles and interclavicle was greater than

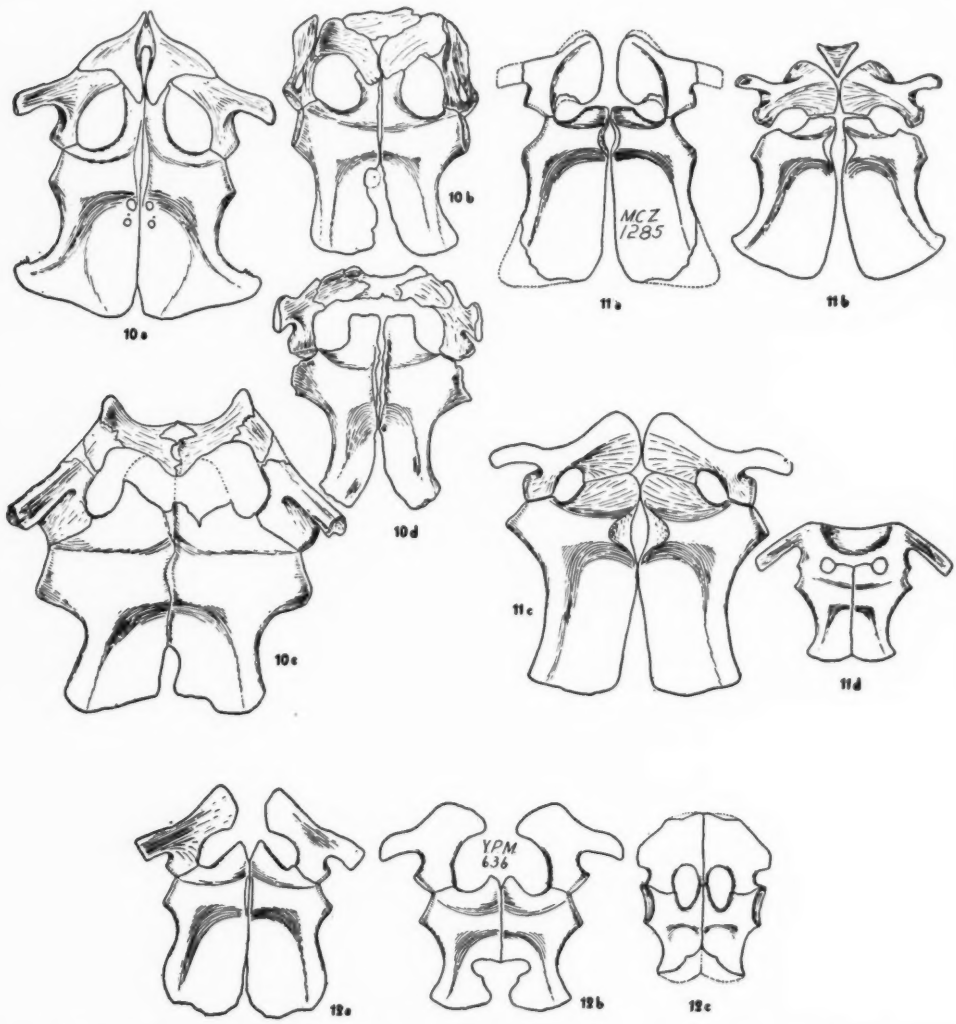


FIG. 10.—Polycotylidae and Leptocleididae; dorsal aspect of pectoral girdles. *a*, *Trinacromerum osborni* Williston, ×1/12, after Williston (1925). *b*, *Leptocleidus superstus* Andrews, ×1/12, after Andrews (1922). *c*, *Rhomaleosaurus thorntoni* Andrews, ×1/18, restored from Andrews (1922). *d*, *Eurycleidus arcuatus* (Owen), ×1/18, after Andrews (1922).

11.—Pliosauridae; pectoral girdles. *a*, *Kronosaurus queenlandicus* Longman, ×1/54, dorsal aspect, Mus. Comp. Zool. no. 1285. *b*, *Peloneustes philarcus* (Seeley), ×1/28, dorsal aspect, after Linder (1912). *c*, *Pliosaurus ferox* Sauvage, ×1/28, dorsal aspect, restored from Linder (1912) and Andrews (1913). *d*, *Eretmosaurus rugosus* (Owen), ×1/15, ventral aspect, redrawn from Seeley (1874).

12.—Elasmosauridae; pectoral girdles. *a*, *Simolestes vorax* Andrews, ×1/30, dorsal aspect, after Andrews (1913). *b*, *Cimoliosaurus snowi* Williston, reduction unknown, dorsal aspect, redrawn from Williston (1906). *c*, *Elasmosaurus platyurus* Cope, ×1/36, ventral aspect, redrawn from Cope (1870).

the diagram shows); scapulae meeting in midline and meeting the coracoids between the scapulo-coracoid fenestrae.

The combination of characters in the pectoral girdle of this genus is unique among the plesiosaurs, and the affinities of this form are not readily evident. It would be easier to derive it from the Brancasauridae than any of the other groups.

Polycotylidae. One point in support is the nature of the claviculo-coracoid union; another, the mesocephalic skull.

POLYCOTYLIDAE Williston, 1908
Figure 10*a*

Dolicocephalic; 19 to 26 cervical vertebrae, 28 to 30 dorsals, 3 sacrals, 25 caudals; cervical ribs single-headed; posterolateral

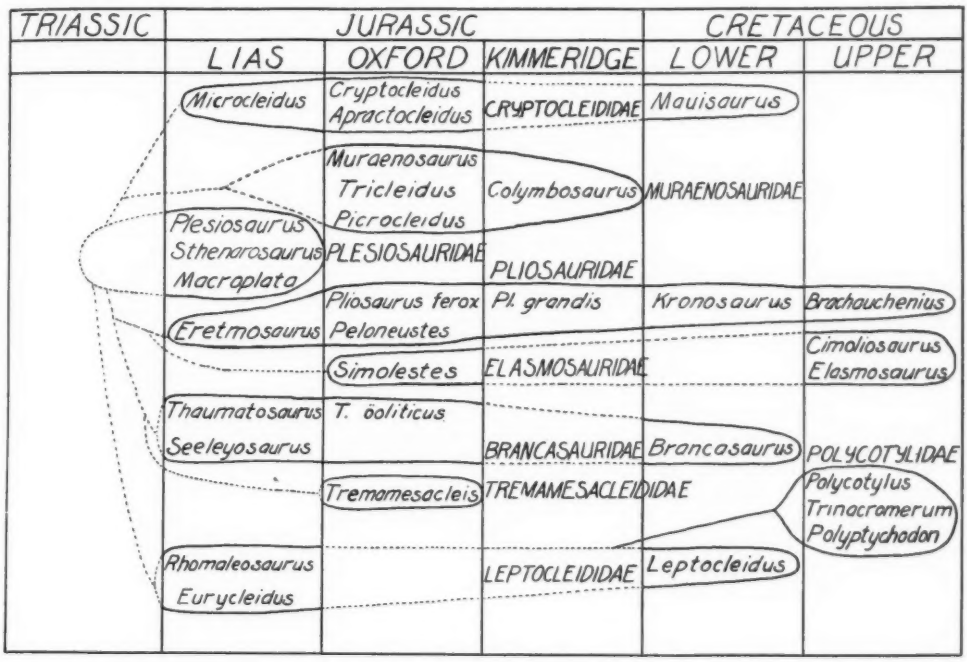


FIG. 13.—Relationships and geological distribution of the plesiosaurs.

LEPTOCLEIDIDAE White, n. fam.
Figures 10*b–d*

Only skull known (*Rhomaleosaurus*) shows beginning of dolichocephaly; 18+ to 27 cervical vertebrae, 27 to 31 dorsals, 34 caudals; cervical ribs single- or double-headed; clavicles and interclavicle present; interclavicle without posterior process, posterior edge may be free and with a broad notch; scapula not meeting coracoid medial to scapulo-coracoid fenestra; posterolateral angles of coracoids not produced.

Included genera: *Leptocleidus, Eurycleidus, Rhomaleosaurus.*

This family is certainly ancestral to the

angles of coracoids produced; clavicles and interclavicles present and well developed; interclavicle enclosing a foramen; scapula not meeting coracoids medial to scapulo-coracoid fenestra, but the union being effected by the clavicles and interclavicle.

Included genera: *Polycotylus, Trinacromerum, Polyptychodon.*

PLIOSAURIDAE Seeley, 1874
Figures 11*a–d*

Dolichocephalic; 11 to 30 cervical vertebrae, 19 to 37 dorsals, 25 to 30 caudals; cervical ribs double- or single-headed; clavicles absent; interclavicle known only in *Pelo-*

neustes; scapula meeting coracoid medial to scapulo-coracoid fenestra; fenestrae small and separated by a broad bar equal in width to twice the diameter of one fenestra; posterior lateral angles of coracoids not produced.

Included genera: *Pliosaurus, Peloneustes, Eretmosaurus, Brachauchenius,* and *Kronosaurus.*

The relationships of this family are not altogether clear, but it is much easier to derive the shoulder girdle from the Brancasauridae than from any other family.

I have included *Eretmosaurus* and *Brachauchenius* because, though imperfectly known, the characters they present compare more favorably with this group than with any other.

Elasmosauridae Cope, 1869
Figures 12*a–c*

Mesocephalic; 20 to 76 cervical, dorsals 30 ±, ? caudals; cervical ribs single- or double-headed; clavicles and interclavicle absent; scapula meeting coracoid medial to scapulo-coracoid fenestra; fenestrae large and separated in mature forms by a bar no wider than the diameter of one fenestra; posterolateral angles of coracoids not produced.

Included genera: *Simolestes, Elasmosaurus, Cimoliosaurus.*

I have included *Simolestes* in this family because the character of both the skull and shoulder girdle compare more favorably with *Elasmosaurus* than with *Pliosaurus* or *Peloneustes.* If Seeley (1892) and Williston (1907) are correct that double-headed cervical ribs are to be correlated with geologically older species, *Simolestes* will serve very well as the Jurassic ancestor of *Elasmosaurus.*

There seem to be several elasmosaurids with a neck of medium length for which the name *Cimoliosaurus* Leidy will suffice until we have more definite information about these forms.

RELATIONSHIPS

As this is in no way an exhaustive treatise of the Plesiosauria I have deliberately omitted those genera which were founded on fragmentary or very poor material as well as those which are considered synonymous with well-established genera.

I have attempted to express the probable relationships of the various groups to each other in figure 13.

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JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 5, PP. 468–480, 7 TEXT FIGS., SEPTEMBER, 1940

CERATOPSIDAE FROM ALBERTA

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ABSTRACT—The genus *Centrosaurus* Lambe is distinct from *Monoclonius* Cope. In *Monoclonius* the nasal horncore is long-based, laterally compressed and recurved, and divided until late in life. The posterior edge of its frill is thin and without hooks or epoccipitals. Cope's Judith River species *M. crassus* and *M. sphenocerus* probably are conspecific, but distinct from *Monoclonius lowei* Sternberg, n. sp. *M. recurvicornis* Cope is referred to *Centrosaurus*. *Brachyceratops* Gilmore may prove to be congeneric with *Monoclonius*. Lambe's species *dawsoni* is removed from *Brachyceratops* and referred to *Centrosaurus*.

Monoclonius lowei, *Centrosaurus longirostris*, and *Chasmosaurus russelli*, all from the Oldman formation in Alberta, are described as new species.

IN 1876 E. D. Cope (4) erected the genus *Monoclonius*. The genotype, which he named *Monoclonius crassus*, included amongst other bones part of a parietal crest. In 1904 L. M. Lambe (8) proposed a new genus and species, *Centrosaurus apertus*, on the basis of coalesced parietals of a ceratopsian from the Oldman formation ("Pale beds") (14) of Red Deer River. At later dates Barnum Brown (1 and 2) described three species of ceratopsians, which he referred to Cope's genus *Monoclonius*. These came from Red Deer River from the same beds that furnished *Centrosaurus apertus*. In *A revision of the Ceratopsia* Lull (12) gave *Centrosaurus* subgeneric rank. In a recent article the writer (17) discussed the *Monoclonius-Centrosaurus* problem and advanced evidence that *Centrosaurus* was generically distinct from *Monoclonius*. Brown believed that the posterior hooklike processes, characteristic of *Centrosaurus*, and the epoccipitals had been worn off the type of *M. crassus* (1, p. 550). But the writer, through the courtesy of Dr. Brown, was permitted to examine Cope's type, and he was convinced that nothing had been eroded and that the parietal was very different from that of *Centrosaurus*.

Specimens recently collected from southeastern Alberta and others from Red Deer River recently prepared add considerably to our knowledge of the Upper Cretaceous ceratopsians. Among them is a part of a skull similar to Cope's *M. recurvicornis*, which skull is referred to *Centrosaurus* (17). In 1915 Lambe (11) removed his species *M. dawsoni* to Gilmore's genus *Brachyceratops*, but a recently prepared skull (8798 G.S.C.) from Red Deer River shows that this species should be referred to *Centrosaurus*. With our present knowledge it seems probable that only two of the species that have been previously referred to *Monoclonius* belong to that genus, i.e., *M. crassus* and *M. sphenocerus*, and Brown (1, p. 449) regards these as conspecific.

In the following description of *Monoclonius* it is not possible to demonstrate that our new specimen is distinct from *M. crassus*, though it certainly is distinct from *M. sphenocerus*, which Brown referred to *M. crassus*. Moreover, the size and shape of the posterior scallops of our new specimen differ from like parts in the type of *M. crassus*.

DESCRIPTION

Family CERATOPSIDAE Marsh
Genus MONOCLONIUS Cope, 1876
MONOCLONIUS LOWEI[1] Sternberg, n. sp.
Figures 1, 2

Type: No. 8790 Geol. Surv., Canada, consists of a skull, complete except for rostral, left maxilla, quadrate and quadrato-jugal, and palatal bones. The right side of the face is crushed, and on this side the coalesced parietals are abnormal. From the Oldman formation (14), Upper Cretaceous, about 15 feet below top of beds, near south-central part of NE ¼, sec. 2, T. 5, R. 5, west of 4th meridian, about 7 miles southeast of Manyberries, Alberta.

The animal was evidently adult but, as shown by the open sutures, it was a moder-

[1] Named in honor of Harold D. R. Lowe, who acted as field assistant for several years.

ately young individual. The limits of most of the bones are well-defined. The missing bones were lost before the skull was buried. It was preserved, right side up, in friable, sandy clay, and part of the bone was badly cracked, and the right side distorted by crushing. Much of the crest was washed out before discovery, but this has been skillfully pieced together by Mr. J. Skillen. Contacts are perfect for the midportion of the crest and most of the posterior edge. The left squamosal is complete and undistorted, and a large section of the left parietal unites with it by suture. The right side of the coalesced parietals appears to have been injured during life, and the right fontanelle seems to have been closed by bony growth. The restoration of the left fontanelle can not be regarded as accurate, as the completed edge is preserved at only two points. Reference to the photograph (figs. 1, 2) shows at once where actual contacts are preserved, for the color of the plaster in the restoration is lighter than the bone. Frost action has separated the supraorbitals from the postorbitals and prefrontals. These have been left where they were, and the intervening spaces filled with plaster to give strength. This displacement of bones has added about 40 mm. to the length of the skull.

Generic characters (emended): Nasal horncore outgrowth of nasals laterally compressed; facial part of skull moderately deep; no interpremaxillary fontanelle; anterior edge of premaxilla almost at right angles to lower border; frontal fossa shallow; postorbitals well developed, forming a broad rectangular surface behind the orbits; squamosals short and well forward, with proximal part standing nearly erect; coalesced parietals arched anteriorly but flattening out posteriorly; posterior edge broad and moderately thin, no hooklike processes at back, no process over fenestrae; fenestrae wholly within parietals; no epoccipitals.

Specific characters: Premaxilla elongate, lower branch separating nasal and maxilla; narial depression oval, longer than high; nasals elongate; nasal horncore with very long base, sharp-edged, tapering to backwardly directed point; no brow horncores; orbit longer than high; scallops on posterior edge of frill large; median notch narrow.

The posterior position of the nasal horn

FIG. 1.—*Monoclonius lowei* Sternberg, n. sp. Type no. 8790, Geol. Survey Canada. Skull, superior view, about ×1/12. *F*, frontal; *J*, jugal; *N*, nasal; *P*, parietal; *Pf*, prefrontal; *Pmx*, premaxilla; *Po*, postorbital; *So*, supraorbital; *Sq*, squamosal.

and the lack of brow horns and epoccipitals might be regarded as primitive characters. The absence of the interpremaxillary fontanelle is in keeping with other forms with short squamosals. In a footnote (12, p. 32) Lull suggests that this penetration might represent a postmortem injury. I would regard this fenestra as a very important character in classification, for it seems to be present in all Ceratopsidae with long squamosals and absent in those in which the squamosal is short. In an occasional skull it seems to have been nearly filled by thin bone, although its outline is definitely shown.

rostral will probably prove to be slender, with the lower branch elongate and not short and thick as in *Centrosaurus*. The lower branch of the premaxilla is a long, broad process extending back to the lachrymal and separating the nasal and maxilla as in *Centrosaurus flexus* (1, pl. 39). The greatest length of the premaxilla is 475 mm.; the greatest height, 250 mm.

As in *Styracosaurus* the naris is oval, with the horizontal diameter greatest. In their description of *Styracosaurus parksi*, Brown and Schlaikjer (3) state that Lambe did not give sufficient depth to allow for crushing of the premaxillae, and that the naris is almost

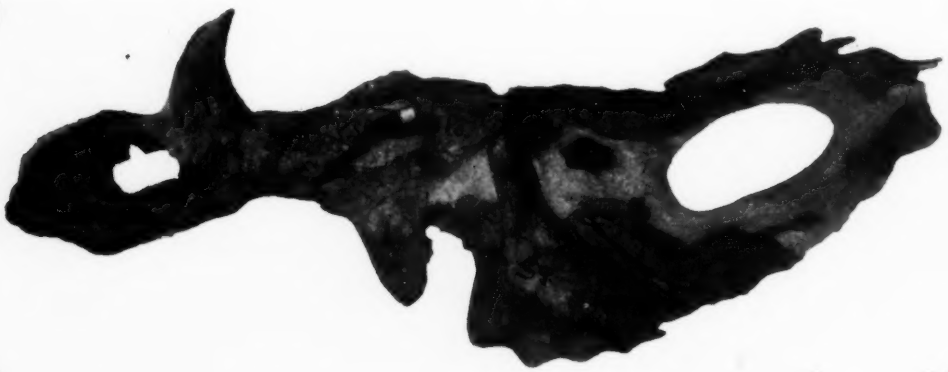

FIG. 2.—*Monoclonius lowei* Sternberg, n. sp. Type no. 8790, Geol. Survey Canada. Skull, from left side, about ×1/12.

The *premaxilla* (fig. 2, Pmx) is well developed, and the thin part that forms the median septum of the nares is longer than in any other short-crested form known to me. This is especially noticeable because the bone is smooth and without fenestration. The front edge stands almost at right angles to the lower border. There is a slight convexity on the inferior surface, but this is less pronounced than in *Centrosaurus* or *Styracosaurus* and is suggestive of that in *Chasmosaurus*. In *M. sphenocerus* the inferior edge of the premaxilla appears to lack any convexity. In *Centrosaurus* (11, pl. 11) the premaxilla rises acutely, forward from this convexity, giving a rounded anterior edge. In *M. lowei*, as in *Chasmosaurus* (11, pl. 8) and in *Triceratops* (7, pl. 44), the inferior edge of the premaxilla continues forward to the tip with no appreciable rise. The circular as in *Centrosaurus*. Though it is true that the premaxilla is vertically crushed in the genotype of *Styracosaurus*, the crushing is not sufficient to have given a circular naris. I believe that the depth given by Lambe (10, pl. 12) is approximately correct.

The *nasal* (fig. 2, N), which is very long and deep, together with the horncore is the largest bone of the face. In advance of the horn the nasal decreases in thickness and terminates 120 mm. in advance of the horncore. This part is much shorter than in *Styracosaurus*. The horncore continues down the side of the face, with no evidence of a base, as in *Chasmosaurus*, *Brachyceratops*, and *Eoceratops*. In none of these species is there the sulcuslike constriction so common at the base of the nasal horncore of *Centrosaurus*.

The long-based, laterally compressed, re-

curved horncore closely resembles that of *Brachyceratops montanensis*, but its position behind the naris is different from that shown by Gilmore (5, fig. 2). It differs also from that shown by Lambe in *Eoceratops canadensis* (11, pl. 1). The position of the horncore with relation to the naris is largely dependent on the angle of the nasal, and as Gilmore's and Lambe's types were both disarticulated, there is a possibility of slight error. If the angle of the nasal of the *Brachyceratops* type were altered so as to place the horncore more upright, the horn would stand over the posterior edge of the naris. In Lambe's restorations of the type of *E. canadensis* the horn is directed too far forward. In most Belly River ceratopsians the anterior tip of the nasal is directed forward and slightly downward, and the anteroinferior tip points forward and downward. In Lambe's restoration these tips point almost directly downward.

In a recent description of an adult *B. montanensis* Gilmore gives a new restoration (6, fig. 11) in which the nasal horncore is shown farther back and the squamosal shorter than in his original restoration. It now seems possible that *Monoclonius* and *Brachyceratops* may eventually prove to be congeneric.

As in *Brachyceratops* and *Eoceratops*, the nasals of *Monoclonius lowei* are divided to the tip of the horncore. This division is regarded as a juvenile character, though in some genera it was apparently more persistent than in others. In all Belly River and Edmonton ceratopsians the nasal horn appears to have been borne on an outgrowth of the nasals and not on a separate ossification as in *Triceratops*. Lambe showed an epinasal in his *E. canadensis* (11, pl. 1, E), but in no other specimen in our collections is there any evidence of such separate ossification.

The anterior-posterior diameter of the nasal horncore at the base is 165 mm.; the greatest transverse diameter is 73 mm., and at midheight 42 mm. The tip stands 188 mm. above the nasals, measured behind the horncore.

The *prefrontal* resembles that of *Brachyceratops*. Anterointernally it meets its fellow on the midline and separates the nasal and frontal (fig. 1, Pf). It is separated from the orbital rim by the well-developed supraorbital. From the midline a suture between the prefrontal and frontal runs out and back to meet the internal corner of the supraorbital.

The *frontals* occupy their normal position on the midline of the skull (fig. 1, F). In the primitive *Protoceratops* both the prefrontal and frontal take part in the formation of the orbital rim; but in Belly River genera the great development and union of the supraorbital and postorbital have forced the frontal from the orbital border. Another important change that has taken place in the later ceratopsian skulls is the folding of the frontals to form a false roof surrounding a large fossa above the brain (see fig. 1). As a result of the open sutures in our specimen, the frontals are splendidly outlined except on the posterior part of the floor of the frontal fossa.

On the surface of the skull the united frontals are lozenge-shaped in outline, but much of the central part is occupied by the broad, shallow frontal fossa (fontanelle). The floor of the posterior part of this fossa is made up of the anterior tip of the coalesced parietals flanked by the frontals. With the posterior extension of the postorbital to roof the supratemporal fossa and unite with the superior edge of the parietal, there has been a backward development of the frontal to keep its normal contacts with the postorbital and give greater strength. As a result of this posterior development, the frontal flanks the anterior tip of the parietal, or that part which overlies the brain. On the midline of the skull the suture between the frontals clearly extends back to the anterior edge of the fossa, a distance of 65 mm., then down to the floor and back to the tip of the parietals. From this point the suture turns almost at right angles and marks the division between the frontal and the anterior extremity of the parietal. Near the outer edge of the floor of the fossa the suture is lost, and the divisions between the posterior development of the frontal and the parietal cannot be determined. It was probably similar to that in *Styracosaurus* (15).

The frontal part of the floor of the fossa is at a somewhat higher level than the tip of the parietals. The greatest length of the frontals is 220 mm.; from the anterior tip to

the parietal, on the midline, 125 mm.; and the greatest breadth, 115 mm.

The process of the parietal, which extends upward to unite with the frontals and form the posterior edge of the frontal fossa, is excavated and smooth. Brown believed that blood vessels passed over this depression to supply nourishment to the base of the horns. In most Belly River ceratopsians the horncore is not hollow, and the frontal fossa is completely separated from the base of the horn by the folded frontal, therefore blood vessels could hardly enter the horncore. In discussing this groove, Dr. T. H. Eaton, Jr., of Schenectady, N. Y., suggested that the frontal fossa may have been the place of origin of an anterior division of the adductor muscle. It is worth noting that this excavation runs from the supratemporal fenestra to the frontal fossa.

The *supraorbital* is well developed and equals or surpasses in size that of *Styracosaurus* and *Brachyceratops*. It makes up more than half of the superior border of the orbital rim. The bone is broad and thick but lacks the buttress effect in front of the orbit that is seen in forms with large brow horns. The anterior part of the bone does not bend down as sharply as in most forms; thus the orbit is less rounded than in *Centrosaurus* or *Styracosaurus*. The greatest length of the supraorbital is 105 mm., the greatest breadth 80 mm., and the greatest thickness, just in advance of the union with the postorbital, is 28 mm.

The *postorbital* resembles that of *B. montanensis* (6, fig. 11) but is relatively larger than in *Centrosaurus*. It extends well behind the orbit and shows a broad, flat surface in this region. Laterally it bends down sharply to form a nearly vertical side to the posterior part of the cranium. There is a low, smooth elevation on the top of the anteroexternal corner of the bone. This is where the horncore is usually developed, but in neither specimen is there evidence of a horncore, and even vascular impressions are lacking. It would seem certain, therefore, that no brow horn was present. Internally the postorbital unites with the frontal by interlocking suture throughout its whole length, and posterointernally it meets the superior tip of the parietal in strong union.

The *parietals* are thoroughly coalesced as in other members of the Ceratopsia. The anterior tip, or that part which overlies the brain, is narrow and thin. This part of the bone was not exposed on the surface of the skull. Posterior to this anterior tip the parietals are greatly enlarged and arched in the forward part though quite flat behind. The center bar is moderately broad, with a low sagittal ridge, which supports four low prominences. Posteriorly the median bar flattens out and is quite broad and moderately thin. The median bar and its posterior expansions are broader than in the type of *M. crassus*. On the posterior edge there are two large scallops on either side of the median notch and one on the posterolateral corner. These are all larger than in Cope's type. The most mesial posterior scallop of the left side is incomplete though perfect on the right side. Number two is not complete, but enough is preserved on the left side to show that it was similar to though larger than number one. The corner scallops are nearly as large as the others; anteriorly they gradually decrease in size and thickness, as in Cope's type.

The posterior part of the parietals is totally different in *Centrosaurus*, for in this genus the edge is greatly thickened and indented and carries two incurved hornlike processes.

The *squamosal* resembles that of *Styracosaurus* more than *Centrosaurus*. It is very short and far forward, with the proximal part almost perpendicular, and the suture between it and the parietal less backwardly inclined than in *Centrosaurus*. There are five scallops on the external border. These are so thin-edged as to preclude the possibility of epoccipitals having been present.

The *maxilla* is more slender than in *Centrosaurus* though otherwise similar. At the anterior end, above the level of the tooth magazine, the bone expands into a thin horizontal plate, which unites with its fellow on the midline and with that part of the premaxilla which forms the roof of the mouth. On the midline a narrow V-shaped trough extends backward from the tip of the beak and above the expanded tips of the maxillae to the narial cavity.

The *teeth* of the known genera of ceratopsians do not differ greatly. The entire crown is covered with a thin coat of enamel. The

functional teeth had all dropped out of the maxilla of the type specimen before burial, yet a number of unworn teeth are preserved and show detailed structure. The external face of the crown is nearly twice as long as broad, and though relatively flat has raised edges and a low median carina placed well behind the middle. The apex is more sharply pointed than in the maxillary teeth of *Triceratops*. From the apex to near the middle of the crown, the anterior and posterior edges are formed by small denticles, which continue for a short distance on both external and internal faces as low, narrow ridges. The external face is relatively more slender than in *Centrosaurus*, and much more so than in *Triceratops*. There are 29 or 30 vertical rows of teeth in a distance of 265 mm.

Measurements.—The dimensions are as follows:

	mm.
Length from tip of premaxillae to orbit	630
Tip of premaxillae to anterior tip of frontals	600
Tip of premaxillae to back of postorbital	900
Tip of premaxillae to back of crest	1645
Breadth across orbits	270
From inferior view:	
Tip of premaxillae to centre of condyle	800
Centre of condyle to back of centre bar	720
Centre of condyle to extreme back of crest	840
Breadth across jugals	470
Breadth (greatest) across squamosals	770
Anterior edge of squamosal to back of crest	900

Genus CENTROSAURUS Lambe 1904

CENTROSAURUS LONGIROSTRIS Sternberg, n. sp.

Figures 3–5

Type: No. 8795 Geol. Surv., Canada, a skull and lower jaws, collected by the writer in 1917. Discovered by G. E. Lindblad in the Oldman formation one mile south of mouth of Sand Creek, quarry 91 on Steveville map (18), 102 feet above Red Deer River. The lower jaws were disarticulated, and the skull preserved right side up. The squamosals, jugals and quadrates were spread outwards by crushing, thus increasing the normal breadth in this region; otherwise there is practically no distortion and the bone is well preserved. Part of the sutures are obliterated by fusion of the bones.

Generic characters: Skull medium-sized; nasal horncore large; brow horncores small or incipient, directly above orbits; rostral short, heavy; premaxillae deep, anteroinferior edge sharply upturned, narial septum nonfenestrated; frontal fossa narrow and deep; squamosals short; coalesced parietals short, broad, well arched, posterior edge thick and bearing two posterior hooklike processes and one or two processes over fontanelles; fontanelles of moderate size, subcircular, wholly within parietals; epoccipitals on border of crest.

Specific characters: Skull in front of orbits elongate and relatively low; nares longer than high; premaxillae long, lower branch not reaching lachrymal; maxillae relatively long; nasals large, nasal horncore pointing forward; orbit higher than long; brow horncores low and massive; parietals very short and broad, deeply indented posteriorly; posterior hooks and anteriorly directed hornlike processes large.

Lambe stated that *Monoclonius flexus* Brown was conspecific with *C. apertus* Lambe (9, p. 21). Parks agreed and referred the fine skull in the Royal Ontario Museum to Lambe's species (13). Lull believes that neither of Brown's species, *flexus* or *nasicornis*, can be shown to belong to the genotype *C. apertus* nor proven to be distinct from it. He regards Lambe's type as of value only in establishing the genus (12, p. 86). I agree with Lull that it is not possible at this time to show which of Brown's species is conspecific with *C. apertus*. It is clear, however, that they are more closely related to each other than either is to the new species *Centrosaurus longirostris*.

The face (fig. 3) is lower and the nose much longer than in *C. flexus* (1, pl. 38). The naris is nearly twice as long as high, whereas in all other known specimens of *Centrosaurus* it is higher than long.

The *rostral* is typical of the genus but rather heavy.

The *premaxilla* is relatively low, and the osseous septum divides the nares to just behind their midlength; in other known species this septum divides them for about two-thirds of their length. The postero-

inferior branch does not separate the nasal and maxilla as it does in *C. flexus*, but, as in *C. nasicornus*, this process overlies the anterior end of the maxilla and ends below the posterior edge of the naris, where it overlaps the anteroinferior process of the nasal. It is thus far removed from the lachrymal.

The *nasal* is the largest bone of the face and is much longer than in other known species of the genus. The nasal horncore is abnormal and the posterior edge is deeply excavated. It was oval at the base and directed slightly forward.

The *orbit* resembles that of *C. nasicornis* in being higher than long. The horncores are very massive and short, with a broadly rounded superior surface.

The *frontal fossa* is narrower and deeper than in *Monoclonius* (fig. 1), *Styrosaurus* (15, pl. 1), or *Chasmosaurus* (fig. 6). On the midline between the brow horns the frontals have united to cover the fossa except for a short distance posteriorly.

The *parietals* are very broad, short, and deeply indented behind. Their length on the midline from the back of the frontal fossa is about half the breadth. The center bar is very heavy throughout, and posteriorly it has a thickness of 52 mm. From the posteroexternal edges of this thickened posterior bar, the hooklike processes so characteristic of the genus run backward and inward.

FIG. 3.—*Centrosaurus longirostris* Sternberg, n. sp. Type no. 8795, Geol. Survey Canada. Skull and jaws, left side, ×1/10.

From the top of the anterior edge of the thickened bar, short broad processes extend forward. These stand well above the fenestrae and extend over only the posterior part.

In the type of *C. apertus* the process which extends forward over the fenestrum is straight and long and rises from the middle of the anterior edge of the cross bar. Also, the suture for union with the squamosal suggests that the squamosal was longer than in *C. longirostris*.

The *maxilla* is relatively longer and more slender than in other species of the genus.

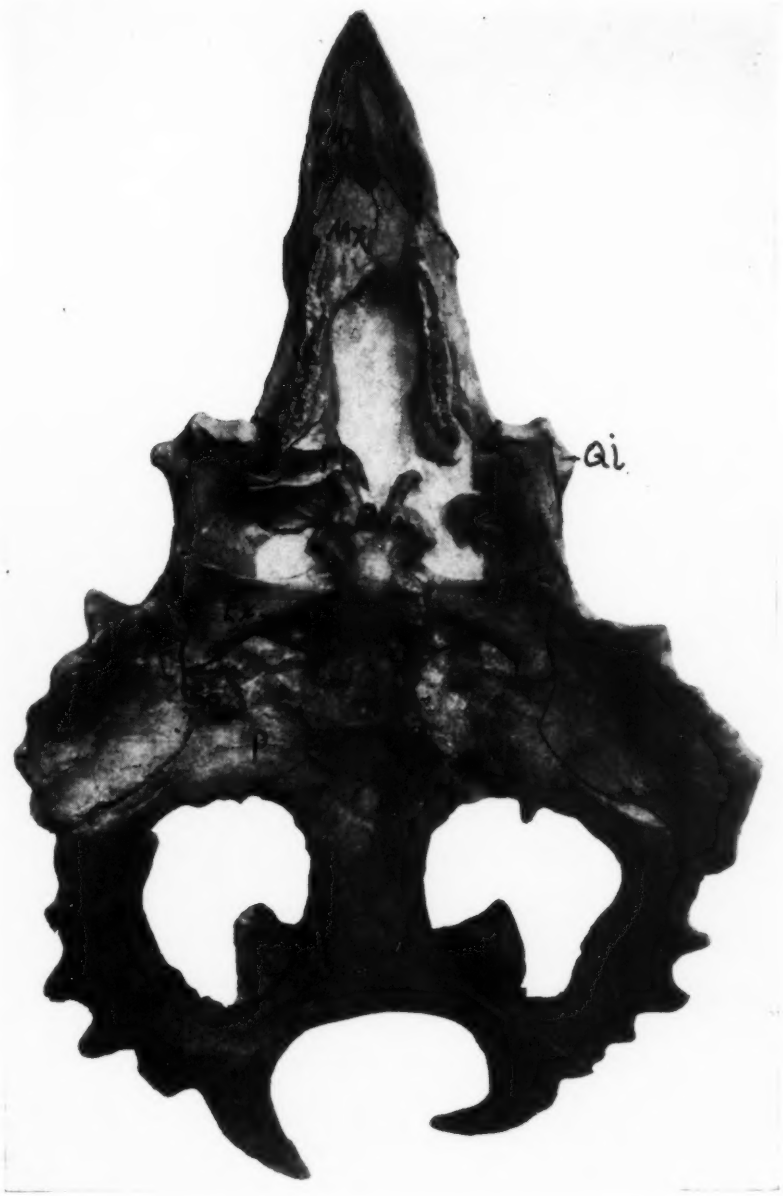

FIG. 4.—*Centrosaurus longirostris* Sternberg, n. sp. Type no. 8795, Geol. Survey Canada. Inferior view of skull, ×1/9. *Bo*, Basioccipital; *Ex*, exoccipital; *Mx*, maxilla; *P*, parietal; *Pmx*, premaxilla; *Pt*, pterygoid; *Q*, quadrate; *Qj*, quadratojugal; *Sq*, squamosal.

Its union with the nasal and jugal are well shown in figure 3.

The *ectopterygoid* (fig. 5, Ept) adheres to the superoexternal face of the posterior part of the maxilla. It is much larger than in *Triceratops*, where, according to Hatcher (7, p. 26), it is reduced to little more than a flattened ossicle. From the apex, near midlength, it extends backward and downward and unites with the pterygoid to embrace the posterior tip of the maxilla. From about midlength its superior part extends forward as a thin tongue of bone. As a result of the narrowing of this anterior part, it does not reach the palatine. Near the external edge,

FIG. 5.—*Centrosaurus longirotris*. Sternberg, n. sp. Type no. 8795, Geol. Survey Canada. Posterior part of right maxilla, with epipterygoid and pterygoid, ×¼.

opposite the apex, there is a triangular thickening of the surface. Except for this thickened area, the bone is thin.

The *pterygoid* and *palatine* (fig. 5) are similar to those of *Triceratops*. The posterior wing of the pterygoid is, however, somewhat larger where it overlaps the flange of the quadrate.

Inferior view.—When viewed from below (fig. 4) the specimen shows splendid details, and with the exception of the supraoccipital region the only distortion is the slight spreading of the squamosals, jugals and quadrates. The left pterygoid and the prevomers were lost before burial. The crest is very broad and strongly arched. The distal ends of the quadrates are about 50 mm. too far forward. (The position of the quadrates was altered before the photograph of the side view was taken.) Due to foreshortening in the photograph, the anterior part of the crest appears too broad.

As in *Monoclonius*, a V-shaped trough extends from the tip of the beak backwards and enters the nares above the expanded tips of the maxillae. This trough increases from practically nothing at the tip to a depth and breadth of 30 mm. at its posterior extremity. Part of the roof of the mouth is formed by the expanded anterior tips of the maxillae, which measure 150 mm. in greatest length and 145 mm. in the combined width.

The *occiput* is splendidly preserved, and except for crushing in the region of the supraoccipitals there is no distortion. When compared with *Monoclonius*, the whole occiput is very massive. The exoccipitals are broader than in *C. flexus* (12, fig. 5) (1, fig. 2). Their combined breadth measures 475 mm., and the anteroposterior expansion of the distal end of the transverse expansion is 160 mm. The superoposterior edge of the transverse wing underlies the forward extension of the lateral part of the parietal. This thin sheet of the parietal in turn underlies the thinning edge of the squamosal. Figure 4 shows the thinness of this part of the parietal: here, just behind the outer edge of the right exoccipital, the parietal has been removed to expose the squamosal. In this region it is 2 mm. thick.

From a plane paralleling the alveolar border of the maxilla, the occipital condyle faces considerably downward, suggesting that in life the nose pointed downward and the crest was well elevated. In this species, at least, the crest was more elevated than Lull has shown it in his restoration of *C. flexus* (12, pl. 2). The crest of *Monoclonius* seems to have been intermediate between this and the relatively flat-lying crest of *Chasmosaurus*.

Lower jaw.—The left mandibular ramus and a considerable part of the right ramus are well preserved, and the sutures are open. The predentary lacks the tip and some of the posterior part. On the left side, the groove, usually seen on the superior edge of the predentary, is not present, and instead the edge is sharply rounded. The right side is normal.

The *dentary* (fig. 3) lacks the pronounced external ridge seen in *C. flexus* (12, fig. 4) and *C. nasicornis* (2, pl. 12, A). There is a longitudinal concavity near the lower edge,

though no "deep hollow" on the upper half as mentioned by Lull (12, p. 37). The greatest depth of the dentary is behind midlength, whereas in Brown's species it is highest anteriorly.

The *angular*, *splenial*, *surangular*, and *articular* are typical of the genus. The splenial is more slender than in *Triceratops*. The anterior edge of the angular is 35 mm. thick and broadly grooved to receive the thickened inferoposterior tip of the dentary. In *Triceratops* this tip is thin and overlaps the dentary (7, fig. 38). It makes up most of the posteroinferior surface of the jaw and extends backward beneath the surangular and articular and ends in a tip at the posterior extremity of the mandible. The internal edge is grooved to receive the splenial. The right angular is 15 mm. longer than the other. The surangular closely resembles that of *C. nasicornus* (2, pl. 12, A). The posteroexternal tip of the mandible, which Lull shows as articular (12, fig. 14, Ar) is certainly part of the surangular in our specimen. Only the posterointernal edge of the articular shows from lateral view. This part of the mandible is therefore shorter than in *Triceratops*. The surface of the articular stands about 5 mm. above the surangular posteriorly; here the surangular is concave and roughened, suggesting the presence, in life, of a cartilaginous pad continuous with the articular.

The articular resembles that of *T. prorsus* as shown by Hatcher (7, fig. 40, A), although it is more massive. The triangular process, which in *Triceratops* extends backward from the articular surface, runs inward and thus is not produced behind the surangular.

FIG. 6.—*Chamosaurus russelli* Sternberg, n. sp. Type no. 8800, Geol. Survey Canada. Skull, approximately ×1/14.

Measurements.—The dimensions are as follows:

	mm.
Total length of skull on midline	1,230
Total length of skull to back of hooks	1,445
Rostral to anterior edge of nasal horncore	290
Rostral to anterior edge of orbit	610
Length of premaxilla	370
Length of nares	320
Height of nares	180
Breadth across orbits	290
Breadth between bases of horncores	100
Length of parietal, midline behind frontal fossa	450
Breadth of parietals (in straight line)	830
Length of squamosal, externally	300
Length of mandible	660
Length of predentary	250
Greatest height of dentary (without coronoid process)	115
Length of dentary	450

Genus CHASMOSAURUS Lambe, 1914
CHASMOSAURUS RUSSELLI[2]
Sternberg, n. sp.
Figures 6 and 7

Holotype: No. 8800, Geol. Surv., Canada, consists of skull without lower jaws. The anterior part of the rostral, the distal half of the left jugal, right jugal, quadrate, and squamosal and a little of the right edge of parietals were destroyed by erosion before discovery. Collected by Dr. L. S. Russell in 1938 from the Oldman formation (upper part) north of center of NE. ¼, sec. 21, T. 2, R. 4, W. of 4th Meridian, or about 17½ miles south and 9 miles east of Manyberries, Alberta.

FIG. 7.—*Chasmosaurus russelli* Sternberg, n. sp. Paratype no. 8803, Geol. Survey Canada. Posterior part of the coalesced parietals, ×1/12.

Paratype: No. 8801, Geol. Surv., Canada, consists of skull and lower jaws. Much of the crest was destroyed by erosion. Collected by the writer in 1928. Discovered by Harold D. R. Lowe in the Oldman formation 3 miles south of Steveville, Alberta, quarry no. 63 on Steveville map (18), 2,198 feet above sea level or about 120 feet above Red Deer River.

A third skull, no. 8802, Geol. Survey, Canada, representing this species was collected by the writer in 1937 near the same horizon as no. 8800 in the NE. ¼, sec. 10, T. 2, R. 5, W. of 4th Meridian, or about 13½ miles south and 3¼ miles east of Manyberries, Alberta.

This skull was near the surface and had been cracked by frost action. The back of the crest had been eroded away, and the top of the nose was injured after the skull was partly buried but before fossilization. The lower jaws are preserved.

A fourth specimen, no. 8803, Geol. Survey, Canada (fig. 7), consisting of the posterior part of the parietals, shows the same deeply emarginate posterior edge as the holotype. This specimen was collected by the writer from the Oldman formation on the South Saskatchewan River in the NW. ¼, sec. 12, T. 30, R. 16, W. of 3rd Meridian, from a bone bed located by Roy Graham in 1935.

Specific characters: Skull large, relatively high and short in front of orbits; rostral straight inferiorly, not hooked downward at tip; nasal horncore massive; broad between orbits; no brow horncores; well-developed epijugal; parietals deeply indented posteriorly; squamosal border not strongly scalloped; epoccipitals small; mandible massive.

The *rostral* is relatively light, and the anterior tip is not downturned. The lower branch is longer than in *C. belli* (11, pl. 8), and it extends well back below the horizontal edge of the premaxilla.

The *premaxilla* is relatively higher than in other species of the genus except *C. brevirosris* (12, pl. 7). The nose resembles that of *Pentaceratops* (12, pl. 5, B) though longer. The superior edge is not raised in front of the nasal horncore, as in *C. belli*. Its unions with the nasal above, and the nasal and maxilla below, are not clearly shown in the holotype, but the paratype no. 8801 shows them to be the same as in *C. belli*.

The top of the skull of the holotype seems to have been injured during life, and the nasals and frontals are deformed. Because of this deformation the shape of the nasal horncore cannot be given, though it seems to have been massive; in 8801 it is massive and of moderate height, and the front edge is truncate. In 8801 the horncore is closer to the orbit than in the holotype.

Although several large foramina extend through the top of the skull, their presence is believed to be due to malformation. The skull has been crushed so as to exaggerate the height and to allow the top of the skull to show from the side view. The right orbit has been crushed upwards to simulate a

[2] Named in honor of Dr. L. S. Russell, who collected the holotype.

horncore, but in none of the three skulls referred to this species is there a well-defined horncore over the orbit. However, the surface above the orbits is rugose, and it is possible that there may have been a short horn.

The *frontal fossa* is shallow and very broad, but no details can be given of the bones surrounding it. Behind its midlength a plate of bone extends across the fossa, though this is probably an abnormal growth.

The *coalesced parietals* are deeply indented posteriorly and do not bear epoccipitals. From the posteroexternal corner of the crest, the parietal extends inward for about 175 mm. and then turns forward and inward to the midline. The development of this element shown in specimen no. 8803 (fig. 7) is similar to that of the holotype, in which crushing has altered the appearance.

As is usual in the genus, the anterior part of the parietal is divided into a superior surface, which is covered with vascular grooves, and a smooth depressed area, which served as attachment for the temporal muscles. Between this smooth area and the anterior edge of the fontanelle the bone, though standing at the same level, is covered with well-defined vascular grooves. The center bar and the posterior edge of the crest, as well as all of the surface of the squamosal, are likewise covered with vascular grooves. The superior excavation of the anteroexternal tip of the parietal is quite pronounced.

The *squamosal* is similar to that of *C. belli*, with the exception that the epoccipitals are more numerous and very small. They are so small and thoroughly fused on the distal part of the squamosal that the edge of the crest appears smooth.

The mandible is missing in the type, but the predentary, both dentaries, and the right coronoid are preserved with no. 8801 and the complete mandible, except predentary, in no. 8802. The mandible differs from *C. belli* mainly in being more robust.

The *predentary* of no. 8801 closely resembles that of *Triceratops prorsus* (7, fig. 35), but the tip is drawn out to a longer, sharper point. The upper, grooved surface is defined by two longitudinal ridges, as in *T. prorsus*. It is quite different from *Centrosaurus nasicornis* (2, pl. 12), in which the tip is strongly upturned, and the superior surface is inclined outward. The horizontal upper surface would conform to the plain lower surface of the premaxilla.

The *dentary* is more massive than in *C. belli* and the coronoid process is broader and heavier. The right dentary of no. 8801 has the complete series of 28 vertical rows of teeth.

The *coronoids* are preserved in nos. 8801 and 8802, and in the former the right coronoid is articulated with the coronoid process. It is similar in size and articulation to that shown by Parks in *Centrosaurus apertus* (13, pl. 3), but the superior edge is more broadly rounded. Anteriorly and superiorly it fits the inner face of the coronoid process, but posteriorly it unites with the inner edge of the surangular, which is wedged between it and the coronoid process. The surangular is more massive than in *C. belli*.

The *teeth* are fewer and larger than in *Triceratops* and considerably larger than in *Centrosaurus*. The 28 vertical rows cover a distance of 370 mm., and the rows near the middle of the dentary are 90 mm. high. The number of teeth in a vertical series cannot be determined, but there certainly are fewer than in *Triceratops fabellatus* (6, fig. 44).

The *scapula, coracoid, humerus, tibia* and *fibula* are preserved with no. 8801. These bones have not been prepared, but field measurements suggest that the fore limb of this species was relatively large as compared with *C. belli*. The humerus is 710 mm. long, the tibia 610 mm., and the fibula 530 mm. These measurements show the humerus to be longer than the tibia, whereas in *C. belli*, no. 2245, Geol. Survey, Canada (16, p. 73) the length of the humerus is 510 mm., of the tibia 535, and the fibula 483 mm.

Measurements.—The dimensions are as follows:

	mm.
Greatest length of skull	1,940
Greatest length of skull on midline	1,740
Beak to anterior edge of orbit	655
Beak to anterior edge of nasal horn	370
Beak to posterior edge of narial opening	430
Back of orbit to back of crest	1,180
Back of orbit to front of parietal fontanelle	510
Length of fontanelle (diagonal)	610
Breadth of fontanelle	280

Breadth of left half of crest (anterior)[3]	620
Breadth of left half of crest (posterior)	430
Depth of premaxilla (greatest).....	275
Depth of face, back of nasal horncore to alveolar border of maxilla.....	310
Breadth across top of orbits, about...	300
Length of frontal fossa.....	180

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[3] This breadth is exaggerated by crushing.

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THESCELOSAURUS EDMONTONENSIS, N. SP., AND CLASSIFICATION OF THE HYPSILOPHODONTIDAE

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ABSTRACT—A new species of *Thescelosaurus* from Alberta is described as *T. edmontonensis*. The inferior surface of its vertebrae are less rugose than those of *T. neglectus*, and the skeleton is more massive and the body broader. The material includes the first-known skull elements and teeth of the genus. The teeth have enamelled, laterally compressed, denticulate crowns. A restoration model shows a much heavier animal than Gilmore's restoration of *T. neglectus*. The species described by Parks as *T. warreni* belongs to a different genus, *Parksosaurus* Sternberg, 1937, of which it is the genotype. *Parksosaurus* is assigned to the Hypsilophodontinae. *Thescelosaurus* is assigned to a new subfamily of the Hypsilophodontidae, the Thescelosaurinae, of which it is the only known representative.

IN 1913, C. W. Gilmore (3) described as *Thescelosaurus neglectus* a new genus and species of orthopodus dinosaur from the Lance formation of Wyoming. Two years later (4) he enlarged on his original description and referred *Thescelosaurus* to the Hypsilophodontidae. In May, 1926, I announced (16) the collection of a skeleton of *Thescelosaurus* from the Edmonton formation of Alberta, but gave no description. This specimen has since been prepared and is the subject of the present study. Toward the end of 1926 the latè Professor W. A. Parks (13) described a new species of orthopodus dinosaur from the Edmonton formation, which he referred to *Thescelosaurus* as *T. warreni*. I have proposed the new generic name *Parksosaurus* for the reception of this species (18).

The drawings illustrating this paper were made by Mr. J. S. H. Lefebvre. The photographs were taken by me but finished by the photographic section of the Bureau of Geology and Topography.

DESCRIPTION

Order ORNITHISCHIA
Suborder ORNITHOPODA
Family HYPSILOPHODONTIDAE
Subfamily THESCELOSAURINAE
Sternberg, n. subfam.
THESCELOSAURUS EDMONTONENSIS
Sternberg, n. sp.
Figures 1–18

Holotype: No. 8537 Geol. Survey of Canada. Consists of articulated column from first dorsal to thirtieth caudal with dorsal ribs, pelvic arch, hind limbs and most metatarsals; and disarticulated frontals, postorbital, mandibular ramus, teeth, cervical vertebrae and ribs, scapulae, coracoids, humeri, ungular phalanx of pes, and fragments.

Horizon: Edmonton formation, Upper Cretaceous.

Locality: SE. ¼, sec. 35, T. 33, R. 22, W. of 4, about 8 mi. northwest of Rumsey, Alberta, near base of gray sandstone bed 260 feet (aneroid) above Red Deer River.

Generic characters: Medium sized; skeleton moderately massive; frontals flat and broad; coronoid process of dentary high and narrow; coronoid and postcoronoid part of mandible high and moderately short; angular and surangular well developed; splenial long, showing from external view; dentigerous border of dentary arched inward; premaxillary teeth small, subconical, without pronounced denticles; striation on faces of maxillary and dentary teeth not parallel, dentary teeth with prominent median ridge; inferior surface of caudal and dorsal centra rugose; vertebral centra subequal in length except at extremities; neural spines of dorsal vertebrae low, thin, well-expanded anteroposteriorly; transverse processes ending abruptly on tenth caudal; ilium thin transversely, superoposterior edge raised high and square-cut behind, superior edge rotated inwardly; ischium flattened, with thin, upturned obturator process on proximal half; manus short, broad, digit II longest, phalanges depressed; femur longer than tibia, pendent fourth trochanter below mid-

length; metatarsals short; phalanges of moderate length, depressed. (Some of these characters may be of higher than generic rank.)

Specific characters: Cervicals slightly rugose on ends of inferior surface but not broad and flat; upward inclination of lateral processes of anterior dorsals less than 45°; capitular process of dorsal ribs not sharply offset; preacetabular process of ilium very thin throughout; blade of ischium expanded and thin beyond obturator process; tibia slightly sigmoid, broadly expanded distally; distal end of fibula overlapping tibia.

Prior to the discovery of this specimen nothing was known regarding the skull or teeth of *Thescelosaurus*. It was therefore a great satisfaction to find a well preserved mandibular ramus with teeth and scattered teeth from both upper and lower jaws, including four premaxillary teeth.

Skull and mandible.—The greater part of the head is missing, but sufficient is preserved to give a fair idea of its general proportions. The approximate length and posteroinferior breadth can be determined from the mandibular ramus, and well-preserved frontals and left postorbital give the approximate shape of the top of the head and the size of the orbit.

The *frontal* (fig. 1) is a relatively large, thin, flat, oblong bone. The anterior extremity is not complete, but apparently very little is missing. The broadest part overhangs the central portion of the orbit, but near the anterosuperior angle of the orbit the bone turns inward and shows sutural contact for the prefrontal. Just internal to this sutural surface the top of the frontal is excavated for the overlap of the posterior tip of the nasal. Near the midline posteriorly, the frontals extend slightly backward for contact with the parietals, and the posterior edge forms the anterior boundary of the supratemporal fossa. That part of the bone which overhangs the orbit thins out to a sharp edge.

Inferiorly the frontal is shallowly excavated for the brain. This excavation is broad behind, narrowing near midlength and broadening again anteriorly. On the inferior surface of the bone a low crescent-shaped ridge, with horns pointing out, runs the length of the bone, separating the brain case from the orbit. This ridge is well-preserved but does not show sutural surface for union with other bones, except posteriorly. This suggests that the braincase was incompletely ossified.

The *postorbital* is a triradiate bone somewhat similar to that of the hooded hadrosaurs (15). The superior and inferior branches make a continuous arc and form the posterior boundary of the orbit. This with the frontal boundary shows that the orbit was large. The greatest length of the left frontal is about 60 mm., and the greatest breadth of the articulated frontals is 58 mm. The thickness near the middle of the braincase is 3 mm. and through the inferior ridge at its midlength 8 mm.

The *left mandibular ramus* is beautifully preserved and complete except the coronoid. All of the sutures are open, and the outlines of the bones are clearly discernible. It is well shown in figure 16. The predentary is not preserved, but a well-defined groove on both superior and inferior surfaces of the end of the dentary shows conclusively that a predentary bone was present in *Thescelosaurus*. The internal mandibular fossa is large and subcircular in outline.

The ramus is of moderate length and resembles that of *Parksosaurus* and to a certain extent *Troödon*. If Parks is correct in his interpretation of the elements in the mandible in *Parksosaurus warreni* (13, pl. 1) the difference between his species and *Thescelosaurus edmontonensis* is very marked. It is probable, however, that part of what Parks shows as dentary really is angular and surangular.

The *dentary* (fig. 16) gradually increases in height from the tip to the posterior extremity, where the coronoid process stands up above the highest point of the surangular. It measures 28 mm. in front of the first alveolus. This is somewhat longer than in *Troödon*. There are alveoli for 16 teeth in a distance of 78 mm. The dentigerous border arches inward as in some of the armored dinosaurs (17, p. 101). There would thus be a large cheek cavity near midlength of the jaw. The Meckelian groove extends the full length of the dentary and terminates near the inferior edge, where it meets the predentary. More than half of this groove is covered by the splenial.

The *surangular*, *angular*, *prearticular* and *splenial* resemble those of *Troödon* (5) more than those of *Parksosaurus* (13).

The large, laterally compressed surangular covers the mandibular fossa externally and with the angular makes up the external surface of the ramus posteriorly. It is quite thin except the superoposterior edge, which overhangs the mandibular fossa internally. Near the base of this edge, on the external surface, a process stands upright nearly parallel to the inner edge. Posterior to this thickened edge the bone extends backward as a low thin process, flanking the articular. The angular is relatively large but thin. It flanks the surangular almost to its posterior extremity and forms the lower edge of the ramus posteriorly. The prearticular is long and thin. It extends from the splenial to the posterior tip of the ramus on the inner face. The splenial is a long thin bone, high behind midlength but pointed at each end. It reaches the alveolar border near the back of the tooth row. Posteriorly it is drawn out into a sharp point, where it is wedged in between the inferior edges of the angular and prearticular.

The *articular* is a small bone wedged in between the surangular and prearticular much as in the hadrosaurs (15, pl. 16).

The *coronoid* is not present, but striations on the superoexternal edge of the surangular suggests that it was a crescent-shaped bone fitting over the tip of the surangular and against the inner face of the coronoid process.

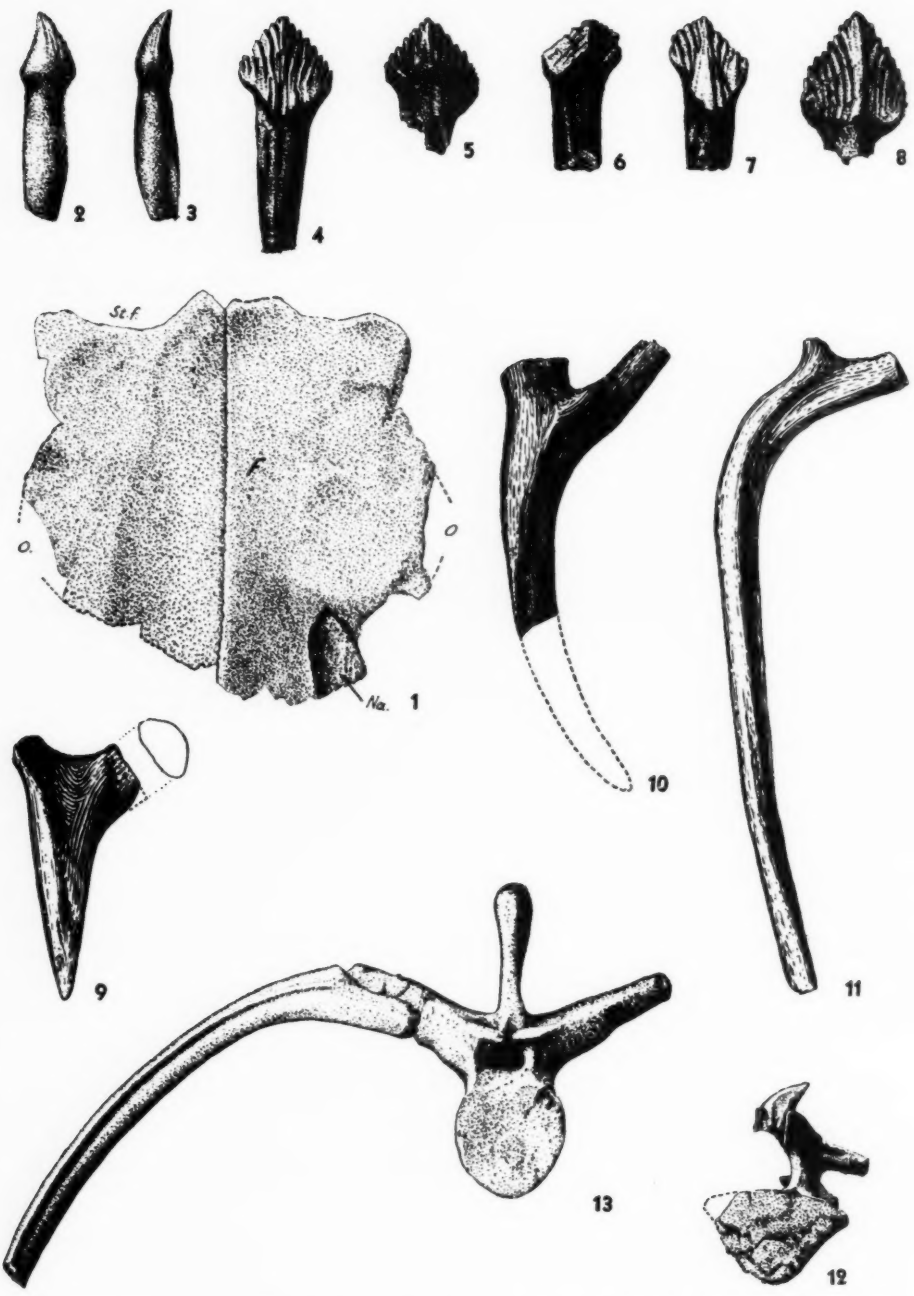
Teeth.—Ten germ teeth are present in the dentary, but no functional tooth remains in place. Nineteen loose teeth were found with the scattered cervical ribs and some skull fragments near the left mandibular ramus. As these show the same structure and sculpturing as those in the jaw, and as bone of no other animal was found with the skeleton, there is no question that all belong to the same individual.

Four of the loose teeth (figs. 2, 3) differ in details from all the others but in general resemble the premaxillary teeth of *Troödon validus* (5, pl. 6, fig. 2). In my opinion there is no question but what these are from the premaxilla, thus proving the presence of teeth in this element in *Thescelosaurus*. These differ from the premaxillary teeth of *T. validus* in being less pointed and lacking distinct denticles. The anterior and posterior edges are not thin as in Troödon except for a short distance near the apex on the anterior edge. The crown is as small as that of any of the other teeth but is relatively thicker internoexternally. Low faint ridges run from the apex to the base of the crown on both inner and outer faces. The fang is almost as large as the crown, long, straight, subcylindrical in cross section and hollow.

In the *maxillary teeth* the crown is convex on the inner or abrasive face but almost flat on the outer face. The apex is high, and the anterior edge is longer and less convex than the posterior edge. In a worn tooth (figs. 6, 7) the anterior edge is quite straight due to the fact that the first and principal wear is on this edge, and even in much-worn teeth the apex is angular. This is evidently the result of each maxillary tooth meeting two dentary teeth rather than the result of the teeth in the two jaws being directly opposite. The free border of an unworn crown is marked by well-pronounced denticles, which point away from the apex. The denticles are compressed cones carrying down as well-defined ridges on both faces of the tooth. The number of denticles varies from ten to seventeen. Viewed externally, a typical crown (fig. 4) is subrhomboidal in outline, and this face is much higher than the inner face (fig. 5). The apical denticle and one on either side merge into a well-defined ridge, which varies in length in different teeth. The inner face is convex anteroposteriorly, and the crown is divided into unequal parts by a well-pronounced ridge, which broadens rapidly from the apex to the base. There is a cingulum on this face.

The *dentary teeth* vary in size, those near the center being the largest. They are larger than the maxillary teeth. The replacement is as in *Hypsilophodon*, but they were not crowded and forced into diagonal rows as in that genus. The teeth are thick medially and slope sharply to the thin anterior and posterior edges.

The inner face of a tooth, in alveolus ten from the front, is splendidly shown (fig. 16, B). The crown is higher and more pointed than in the maxillary teeth. According to Parks the reverse is true in *P. warreni*.



FIGS. 1–13.—*Thescelosaurus edmontonensis* Sternberg, n. sp. Geol. Survey Canada, type no. 8537. Detailed explanation on page 485.

The apical denticle is near the center of the face, and there are 10 smaller denticles on either side.

In size, shape, and sculpturing of the faces, the teeth differ markedly from those of *Parksosaurus* and *Hypsilophodon*.

Vertebrae and ribs.—The skeleton of *T. neglectus* has been so well described by Gilmore (4) that it is not necessary to give detailed description here except as differences occur.

The number of cervical vertebrae is still to be determined, but the complete dorsal series is present. We have 1 cervical, 16 dorsals, 6 sacrals and 30 caudals. What is regarded as the first dorsal vertebra carries a typical thoracic rib (fig. 11), which extends well below the scapula. Whether or not this rib was attached to the sternum cannot be determined, and it may represent the one in advance of what Gilmore regarded as the first dorsal. What he regarded as dorsal 16 might be what is here regarded as sacral 1, for Gilmore gave only five sacrals.

One *cervical centrum* (fig. 12) with half of the arch is preserved. This is regarded as the third from the last or number seven. The centrum is about the same size and proportions as the cervical figured by Gilmore (4, fig. 1). The ventral surface is slightly corrugated, but it lacks the flattened under surface so noticeable in *T. neglectus*. Part of the central portion of the inferior surface is missing, but both ends are present. Anteriorly the inferior surface is narrowly rounded, and posteriorly it is moderately rounded. Judging from the sides of the centrum, the middle of the inferior surface was keeled. The diapophysis is similar to that in *T. neglectus*, but zygapophyses are more slender.

The *dorsal vertebrae* are subequal in length except the last one, which is the largest of the series. The inferior surfaces are narrowly rounded, with a suggestion of a keel near the middle. There is no evidence of pinching in of the sides, but they are gently rounded superoinferiorly.

The transverse processes of the anterior dorsals are much lower than in *T. neglectus* (4, fig. 4), the angle being less than 45°. Posteriorly this angle increases, contrasting with *T. neglectus*, in which the reverse is true. Just in front of the last dorsal the column is broken down, and details regarding the posterior ribs are lacking. The bluntly ended diapophyses suggest that dorsals 14 to 16 carried single-headed ribs. Such a rib is preserved with the sixteenth dorsal. Dorsal 13 has a fairly long, slender, double-headed rib, in which the capitular process is about 15 mm. in length.

The *sacrum* consists of six vertebrae with the centra fused. This is one more than is given by Gilmore for *T. neglectus*. This may be a matter of interpretation, however, as the anterior end of sacral two is somewhat expanded to conform to the broad first centrum. Gilmore states that the first two sacral ribs unite with the centra intervertebrally, while the remaining three articulate laterally with their respective centra. In our specimen there are also five sacral ribs supporting the ilium, but they spring from six centra. The base of the first sacral rib is very broad and extends from near the middle of the first sacral vertebra to well onto the second. As the first of these six centra is thoroughly fused with the second and shows no evidence of a free rib or of a lateral process, and as the first sacral rib springs from this as well as the next centrum, it is regarded as being part of the sacrum. The fusion can hardly be attributed to old age, because the

EXPLANATION OF FIGURES 1–13

FIG. *1*—Frontals, ×1. *F*, Frontal; *Na*, nasal overlap; *O*, orbit; *St. F*, supratemporal fossa.
2, *3*—Premaxillary tooth, ×2.
4—Left maxillary tooth, external view, unworn ×2.
5—Right maxillary tooth, internal view, unworn, ×2.
6, *7*—Left maxillary tooth, worn, ×2; *6*, internal view; *7*, external view.
8—Left dentary tooth, internal view, unworn, ×2.
9—Fouth (?) left cervical rib, ×1.
10—Sixth (?) right cervical rib, ×1.
11—First right thoracic rib, ×½
12—Seventh (?) cervical vertebra, anterior view, ×½
13—Fourth dorsal vertebra with part of rib naturally articulated, anterior view, ×½.

separation of the neural arches on the anterior dorsals suggest a young animal.

The spinous processes are not united as in *T. neglectus* but, as in that species, they extend only slightly above the ilia.

The *caudal vertebrae* do not differ materially from those of *T. neglectus* except that the anterior spines are less inclined backward. As in that species the lateral processes end abruptly on the tenth vertebra. There is very little difference in the length of the preserved caudal vertebrae. Their gradual decrease in other dimensions, however, make the posterior centra appear elongated.

The tail is very different from *Parksosaurus warreni*, in which the centra are described by Parks as being round, much wider than long, with broad, low spines, lateral processes pointing downward and given off from well down on the centra. A few ossified tendons are present along the neural spines near the base of the tail but none farther back or below the centra as in *T. neglectus*. This would suggest that in younger animals the tendons had not ossified. The tail is so well preserved that they would surely be shown if they had been ossified. Ossified tendons are preserved on both sides of the neural spines of the dorsal vertebrae.

Cervical ribs are shown in figures 9 and 10. The former is thought to be no. 4. The tuberculum and capitulum are not widely separated as they are in those farther back, and the large capitulum is borne on a very short neck quite different from that of no. 6 (fig. 10). When articulated, the anterior ribs probably stood out straight from the vertebrae, giving a broad neck.

The *thoracic ribs*, especially the anterior ones, are relatively long and heavy. They resemble those of *T. neglectus* except that the capitular processes are not given off at so sharp an angle from the main shaft of the ribs. In most of these ribs the capitular process is a continuation of the broad curve of the main shaft of the rib. This would throw the rib well up when articulated, and make a broad body even in the anterior region, where the lateral processes are low. Figure 11 shows the first thoracic rib from the right side. It is moderately straight and narrowly rounded proximally, but, continuing backward, the ribs become broadly rounded so as to give a broad back posterior to the fourth vertebra. Figure 13 gives an idea of the cross section of the body at the fourth thoracic vertebra. The fourth rib is fairly heavy and about 300 mm. in length. In cross section this rib is roughly T-shaped with the stem of the T short and rounded. The superior surface is broad and relatively flat.

Sternal ribs are represented by several fragments which are scattered through the rock.

Pectoral and pelvic arches.—The *scapula* is short and broad, and the posterior edge is broadly rounded and downcurved. The posterior edge is thin and does not seem to suggest a suprascapula. The shaft is much constricted just behind the glenoid fossa, and there is no short prominent ridge on the external face above the articulation for the coracoid as in *T. neglectus*. The united scapula and coracoid are strongly arched to conform to the side of the chest. The greatest length of the scapula is 208 mm., the greatest breadth 108 mm., and the least breadth 38 mm.

The *coracoid* is large, broadly rounded anteroposteriorly, and heavy where it articulates with the scapula. That part of the coracoid contributing to the glenoid fossa is thick but no thicker than the contribution of the scapula. The coracoid foramen is in about the same position as shown by Gilmore but is very small.

The *ilium* (fig. 17) stands almost erect in its posterior half, but from midlength forward the superior border gradually arches inwardly, and the anterior end is almost horizontal. This seems to be different from the ilium of *Thescelosaurus* figured by Romer (14, fig. 14) in which the posterior end is low, and the inferior edge appears to overhang externally. The preacetabular part is very thin internoexternally throughout its length, contrasting with the triangular cross section in *T. neglectus*. Posteriorly the ilium is cut off almost straight, much as shown in outline by Gilmore. Its greatest height is near the posterior extremity.

The ilia stands well out from the sacrum, giving a broad back, and the acetabulae are well apart. In the type of *T. neglectus* the ilium is bowed from front to back, and the extremities of the bones are farther apart than the central part. This is not so in *T. edmontonensis*.

The *pubis* does not appear to differ greatly from that of *T. neglectus*, which has been well described by Gilmore.

The *ischium* resembles *T. neglectus* but the distal blade is broader. The proximal ends of the ischia are well apart but from here they run inward, backward, and downward to the obturator process. The obturator processes point inward and forward and approach each other. This gives a large suboval opening between the sacrum and the ischia. A somewhat similar opening is seen in *Camptosaurus* (2, fig. 31). Between the proximal end and the obturator process, the shaft is rotated about 45° and from here backward the anteroinferior edge of the blade approaches that of its fellow, forming an angular trough superolaterally.

Limbs.—The *humeri* are the only parts of the fore limbs preserved with our specimen. The left humerus (fig. 14, A, B) does not appear to differ greatly from the humerus of *T. neglectus*, except for greater proximal width. It is 215 mm. long and the greatest breadth, proximally, is 65 mm. and distally 44 mm. The least diameter is 22 mm. The presence of the head overhanging the posterior border, the twisting of the bone, and the position of the distal condyles suggests that, in normal position, the humerus pointed well out from the scapula as in the Ceratopsia (10, fig. 21).

FIGS. 14, 15.—*Thescelosaurus edmontonensis* Sternberg, n. sp. Geol. Survey Canada type no. 8537; *14*, Internal (*a*) and external (*b*) views of left humerus, ×⅓; *15*, external (*a*) and anterior (*b*) views of right tibia and fibula, ×⅓.

The *femur* is relatively shorter and more massive than in *T. neglectus* but in other respects closely resembles it.

The *tibia* (fig. 15 A, B) resembles that of

T. neglectus in its proximal part, but its distal end is much broader and thinner in the fore-and-aft direction. Gilmore shows the distal end of the tibia as fairly thick, fore and aft, and only 77 mm. broad, whereas in *T. edmontonensis* it is thin anteroposteriorly, and the expansion is 95 mm. Whereas in *T. neglectus* the distal end of the fibula lies beside the tibia, in *T. edmontonensis* it lies on the anteroexternal face. This expansion cannot be accredited to distortion, for both tibiae are splendidly preserved, and both show the same development.

The proximal end is expanded fore and aft, and when viewed from the front presents a narrow surface. Passing down from this point the bone rotates so that below midlength the anterior face is flat. The bone broadens rapidly as it approaches the distal end, where it bends inwardly. The proximal articulation faces upward and backward, but when this bone stands with the distal end inclined backward it articulates perfectly with the distal condyles of the femur.

The *fibula* (fig. 15 A, B) resembles that of *T. neglectus*, but distally it lies on the face of the tibia, whereas in *T. neglectus* it flanks that bone.

Measurements.—The measurements are as follows:

Length of femur	320 mm.
Greatest diameter proximately	108 mm.
Greatest diameter distally	84 mm.
Least diameter of shaft	47 mm.
Length of tibia	290 mm.
Greatest diameter proximately	92 mm.
Greatest diameter distally	95 mm.
Fore and aft diameter distally	30 mm.
Least diameter of shaft	30 mm.
Length of fibula	270 mm.

The second, third, and fourth metatarsals are present and articulated in both feet, but the first and fifth are not preserved in either foot. An ungual and one other phalanx of the pes are preserved. The parts preserved are so similar to those of *T. neglectus* that there is every reason to believe that the feet were similar in the two species.

RESTORATION AND MODEL OF THESCELOSAURUS EDMONTONENSIS

The skeleton has not been removed from the rock in which it was found. Only the right scapula, coracoid, humerus, first dorsal rib, and the cervical vertebra and ribs were changed from their original position. I have followed Gilmore in regarding the number of cervicals as nine. In the restoration of the head I have been guided largely by the preserved elements and comparison with other orthopodus dinosaurs. In restoring the feet and forearms we have been guided by casts of these parts from the type of *T. neglectus*, kindly lent me by Mr. C. W. Gilmore, curator of fossil vertebrates in the U. S. National Museum. All restoration has been left sufficiently lighter in color to be easily recognized from the original bones. The preserved parts of the head and teeth have not been inserted in the mount but left where they will be available for examination by visiting palaeontologists.

The length of the articulated column as preserved, is 8 feet, and the total length, with restored parts, measured over the top of the head and the tops of the neural spines is 11 feet, 4 inches.

Gilmore states that in preparing his restoration model an attempt was made to express the light, agile nature of *Thescelosaurus* (4, p. 615). The fairly heavy ribs and limbs, the short, broad scapula, and the broad back do not suggest to me that *Thescelosaurus* was as slender as shown by Gilmore in his model.

In making the restoration model of *Thescelosaurus edmontonensis* (fig. 18) careful measurements were made of the breadth of the back and depth of the body cavity, and length and proportions of all parts. The rather massive femur and tibia with the short, heavy feet suggest well-muscled hind limbs. Skin impression over the limbs of the type of *Lambeosaurus clavinitialis* suggests that in the hadrosaurs at least the femur was enclosed in the flank. It does not seem likely that the hind limbs of *Thescelosaurus* would be cut away as much from the body as shown by Gilmore. The outstanding humerus looks very odd, but the structure of the bone with the head on the side of the proximal end will not permit any other articulation. The length of the neck is problematical, but its articulation nearly at right angles to the axis of the jaws is believed to be correct. The shape and angle of the occipital condyle in the hadrosaurs *Troödon*, *Camptosaurus*, and *Hypsilophodon*, and the usual position of the neck in most articu-

FIG. 16.—*Thescelosaurus edmontonensis* Sternberg, n. sp. Left mandibular ramus of Geol. Survey Canada type no. 8537, ×1. *A*, External view. *B*, Internal view. *Ang.*, Angular; *Art.*, articular; *D.*, dentary; *Pr.a.*, prearticular; *Sa.*, surangular; *Sp.*, splenial.

FIG. 17.—*Thescelosaurus edmontonensis* Sternberg, n. sp. Geol. Survey Canada, type no. 8537. Articulated skeleton, about ×1/12.

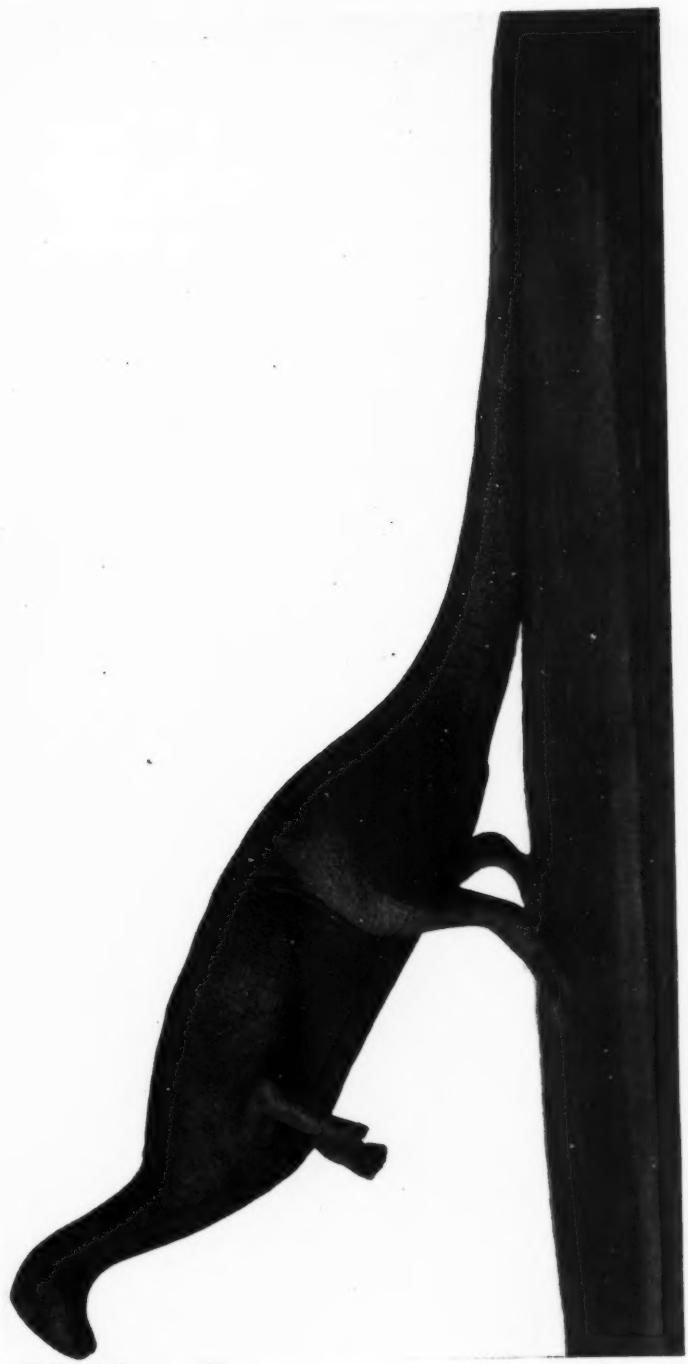


FIG. 18.—*Thescelosaurus edmontonensis* Sternberg, n. sp. Restoration model, $\times \frac{1}{16}$.

lated hadrosaur skeletons that I have collected, suggest that in most orthopodus dinosaurs the skull was carried somewhat as shown here. Available measurements show that the head was very small. An attempt was made to suggest a nonimbricating scale covering without showing much detail. This, of course, is hypothetical. The size of the scales may be exaggerated. The pose chosen is that of an animal looking up from his feeding.

CLASSIFICATION

Careful study of Parks' description and figures of *Thescelosaurus warreni* (13) has brought out notable differences between his species and the known species of *Thescelosaurus*. In structure and proportions, the limbs and feet more closely resemble *Hypsilophodon* than *Thescelosaurus*. The similarities and differences between *Thescelosaurus* and Parks' species are shown in the table of comparisons, in which the characters given for *Thescelosaurus* are those common to *T. neglectus* and *T. edmontonensis*.

From the comparisons in the table it is evident that *warreni* should not be referred to the genus *Thescelosaurus*. The new genus *Parksosaurus* Sternberg, 1937, has been proposed (18) to receive it. *Thescelosaurus warreni* is the genotype. *Parksosaurus* is referred to the Hypsilophodontidae, in which the genotype, *P. warreni*, Parks was originally placed.

Gilmore referred *Thescelosaurus* to the Hypsilophodontidae (4) largely because of the presence of single-headed ribs on the posterior dorsals and four phalanges in digit III of the manus. We now know that single-head ribs on the posterior dorsals are also present in *Dryosaurus* (6) and *Edmontosaurus* (9) and four phalanges are present in digit III of the manus in the Protoceratopsidae (7), Ceratopsidae (1), and Psittocosauridae (12).

In *Thescelosaurus*, as above described, the crown of the teeth is fully enamelled and sculptured on both faces as in the Nodosauridae (17, pl. 3) and Troödontidae (5, pp. 26–27).

COMPARISONS

	Thescelosaurus	*"T." warreni*
Teeth:	Fully enamelled; variable, mostly large.	Fully enamelled; uniformly small.
Face of teeth:	Prominent central ridge; numerous lateral flutings covering faces of tooth, but not parallel.	No prominent central ridge; parallel flutings.
Crown of teeth:	Pointed, wear on two edges	Rounded, flat when worn.
Dorsal vertebrae:	Longer than wide.	Wider than long.
Anterior caudal:	Higher than wide, longer than high.	Round, shorter than high.
Lateral processes:	Point outward and upward, ending abruptly on tenth caudal.	Point outward and downward, gradually decreasing in length.
Caudal spines and chevrons:	Moderately long and narrow.	Short and broad.
Scapula:	Short, greatly expanded superiorly.	Moderately long and narrow.
Ilium:	High, truncated posteriorly, very narrow and thin anteriorly, with superior edge bending inwardly.	Narrowly rounded posteriorly, pointed anteriorly, with superior edge turning outwardly.
Ischium:	Long, straight, thin posteriorly, obturator process well above midlength.	Short, boomeranglike obturator process well below midlength.
Pubis:	Prepubis short, round; postpubis long and slender.	Prepubis a small angulated rod; postpubis absent.
Femur:	Longer than tibia; head separated by necklike constriction; great trochanter rounded, lesser trochanter well developed and outstanding, fourth trochanter below midlength.	Shorter than tibia; great trochanter drawn out to narrow edge, lesser trochanter scarcely defined, fourth trochanter above midlength.
Tibia:	Medium length; extremities strongly rotated.	Long, slender; extremities slightly rotated.
Metatarsals:	Short, heavy.	Moderately long and slender.
Phalanges:	Moderate length; unguals depressed, like a pointed hoof.	Long, high, unguals high, narrow, clawlike.

In a recent paper Swinton (19) has given new information regarding *Hypsilophodon* and made notes on the classification of the Hypsilophodontidae. He does not place much importance on the fact that the crown of the teeth of *Thescelosaurus* are fully enamelled whereas in *Hypsilophodon* they are described as enamelled on one side only (20, p. 395). Most palaeontologists regard this as very important. Noposa (11) makes it a subordinal character and Woodward (20) uses it for family determination. It seems to me that the tooth development and presence of enamel covering the whole crown is of basic importance, and I would expect it to be constant within the family.

Through the courtesy of Dr. Madeleine Fritz and Mr. L. Sternberg of the Royal Ontario Museum of Palaeontology I was permitted to examine the teeth of the type of *Parksosaurus warreni*. These are fully enamelled and sculptured on both faces.

In discussing the premaxillary teeth of *Hypsilophodon*, Hulke (8, p. 1041) says that "both surfaces are highly polished and smooth." In a personal communication, Dr. W. E. Swinton writes:

> I have recently re-examined the whole of the *Hypsilophodon* material and can say with certainty that the ornamented surfaces of the crowns of the teeth, i.e., the outer surfaces above and the inner surfaces below, have a thin veneer of enamel. No such layer, however thin, is to be seen on the grinding surface of the teeth, but it must be remembered that even the youngest tooth soon comes into wear, and the explanation may be that in all of the teeth available for inspection none is young enough to have preserved any enamel unworn.

The assignment of *Parksosaurus* to the Hypsilophodontidae seems justified, and as it is now known that the crowns of the teeth of this species are fully enamelled, I am forced to conclude, as suggested by Swinton, that both faces of the unworn crown of the teeth of *Hypsilophodon* were enamelled. If this be so, the greatest objection to the assignment of *Thescelosaurus* to the Hypsilophodontidae is removed.

Swinton (19) regards the tibio-femoral ration as very important in classification and questions the measurements given by Gilmore. Gilmore's photograph and restoration of *T. neglectus* show clearly that the femur is longer than the tibia, and the same is true of *T. edmontonensis*.

This difference in tibio-femoral ratio in *Thescelosaurus* as compared with *Hypsilophodon* or *Parksosaurus*, taken with other characters, forms a good basis for subfamily separation. The classification of these genera might be characterized as follows:

Family Hypsilophodontidae

Small to medium-sized Ornithopoda. Premaxillae with teeth, mandibular and maxillary teeth in one row only. Orbits large. Cervical vertebrae amphiplatyan or slightly opisthocoelous, six vertebrae in sacrum. Ischium dilated proximally. Pubis and ilium elongated. Manus with five digits, iii with four phalanges; iv and v reduced. Femur, with prominent "pedant" fourth trochanter, shorter than tibia; pes with five digits, but metatarsal v vestigial." Swinton, 19, p. 574.

To this can be added: Head small; teeth laterally compressed, completely enamelled, with multicuspid crowns. We must eliminate Swinton's characterization, "Femur . . . shorter than tibia."

Subfamily Hypsilophodontinae

Scapula of moderate length; forelimb slender; manus elongated and slender; femur shorter than tibia, fourth trochanter above midlength; tibia elongated, slender; pes long, ungular phalanges laterally compressed, clawlike. Known genera: *Hypsilophodon*, Wealden, Isle of Wight; *Dysalotosaurus*, Kimmeridgian, Tanganyika; *Parksosaurus*, Edmonton, Alberta.

Subfamily Thescelosaurinae Sternberg, n. subfam.

Scapula short and broad; forelimb moderately robust; femur longer than tibia, fourth trochanter below midlength; tibia robust, pes short, robust, ungular phalanges depressed, hooflike, though pointed. Known genus, *Thescelosaurus*, Edmonton, Alberta, and Lance, Wyoming and Saskatchewan.

In June 1937, I suggested (18) the erection of the family Thescelosauridae for the reception of *Thescelosaurus*. Further consideration, however, has convinced me that a truer picture of the relationships of these forms would be given by the above classification.

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CRANIAL FORAMINA OF NORTH AMERICAN BEAVERS

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ABSTRACT—An analysis of the cranial foramina of *Paleocastor*, *Eucastor*, *Castoroides*, and *Castor* shows that there is a marked stability of the foramina in the Family Castoridae. It indicates a close relationship between *Eucastor* and *Castor* and supports the contention that *Paleocastor* is not ancestral to later North American genera. *Castoroides* does not seem to have been derived from *Eucastor*. Descriptions and figures of the foramina in the skulls of the four genera are included. A new species of *Paleocastor*, *P. milleri*, is described and figured.

DURING a study of the morphology of a series of therapsid skulls from South Africa, it has been necessary for the writer to examine the skulls of various living and fossil mammals. A particularly fine series of Miocene beaver skulls collected during the last ten years by Mr. P. C. Miller of Walker Museum and a number of skulls from the collections of the Field Museum of Natural History have yielded information of considerable interest. Figures and descriptions of the skulls and in particular of the cranial foramina of certain beavers from the Miocene, Pliocene, Pleistocene, and Recent are presented in this paper.[1] A description of a new species of *Paleocastor* from the lower Harrison beds is included.

I wish to express my appreciation of the generosity of the Field Museum of Natural History in permitting me to study the specimens of fossil and recent beavers included in its collections. And particularly, I wish to thank P. O. McGrew of the Field Museum for his aid in the preparation of this paper.

ORDER RODENTIA
Family CASTORIDAE
PALEOCASTOR MILLERI
Olson, n. sp.
Figures 1–3

Holotype.—*Paleocastor milleri*, Walker Mus. 1582. Well-preserved skull with otic and occipital parts missing. Lower jaws with left ramus partly incomplete.

Horizon and locality.—Lower Harrison, Miocene. Niobrara River, Wyoming.

Diagnosis.—Dental formula 1.0.1.3./1.0.1.3. Crown pattern of premolars and molars very similar to that of other species of *Paleocastor*. Incisor surface slightly convex.

Lengths of dentition[2]: Upper cheek series, 10.6 mm.; lower cheek series, 11.9 mm.; upper diastema, 17.0 mm.; lower diastema, 10.0 mm.

Sagittal crest lyrate, lambdoidal crest low. Apex of palatal notch opposite posterior border of M^3. Nasals fairly broad posteriorly. Interparietal small, restricted posteriorly. Infraorbital foramen partly covered by masseter major muscle.

Measurements of skull: Length of dorsal surface from anterior end of nares to posterior of lambdoidal crest, 48.0 mm.; interorbital width, 10.0 mm.

Paratype.—A specimen consisting of the posterior part of a skull and lower jaws, Walker Mus. 1583, is designated as a paratype. It complements the holotype in showing the characters of the occiput and otic region. Specific identification is based upon the presence of a lyrate sagittal crest and the characters of the dentition. The tympanic bullae are low and distinctly kidney-shaped. The occipital plate is flat. The specimen is slightly smaller than the holotype.

Measurements of dentition: Length of upper cheek series, 9.3 mm.; length of lower cheek series, 10.5 mm.

Comparison with other species of Paleo-

[1] The skulls examined in this study include *Paleocastor simplicidens*, Walker Mus. 1461, 1575, 1576, 1577, 1578, 1579; Field Mus. P12217, P12216; *Palaeocastor fosser*, Walker Mus. 1484, 1580, 1581; *Paleocastor milleri* Olson, n. sp., Walker Mus. 1582, 1583; *Eucastor tortus*, Field Mus. P15787; *Castoroides ohioensis*, Field Mus. *Castor canadensis*, a series of skulls from the Field Museum and Walker Museum.

[2] Measurements taken at occlusal surface of teeth.

castor.—The two previously described species which were studied in the preparation of this paper form the best basis of comparison, since they are well known, and since the other species can be differentiated only with difficulty. *Paleocastor milleri* differs from these two species and from all described species of the genus in the possession of a lyrate sagittal crest. The lambdoidal crest of the new species is not so high or sharp as that in either *P. simplicidens* or *P. fosser*. There is little in the dentition to separate the three species. The position of the apex of the palatal notch of *P. milleri* is comparable to that in *P. simplicidens* but quite different from that in *P. fosser*, in which the apex lies well back of M^3. The tympanic bulla of the new species is similar in shape to that of *P. fosser* and quite different from the high, rounded bulla of *P. simplicidens*. *P. milleri* is smaller than the average *P. simplicidens* although not smaller than some individuals. It is distinctly smaller than *P. fosser*. Comparisons of the cranial foramina are taken up in the following section of this paper. The interparietal of the new species is much narrower posteriorly than that of *P. simplicidens* and *P. fosser*.

CRANIAL FORAMINA

In the following paragraphs a brief analysis of the principal foramina in the skulls of *Castor*, *Castoroides*, *Eucastor*, and *Paleocastor* is presented. The morphology of the skull elements of all the genera except *Eucastor* have been adequately described elsewhere. Peterson (3) has given an extensive account of the skulls of *Paleocastor*, and his work has been supplemented by that of Stirton (5). Hay (1) and Schreuder (4) have given adequate accounts of *Castoroides*, and *Castor* has been discussed in these and other papers. The skull of *Eucastor tortus* has never been fully described, but since this will be dealt with elsewhere by P. O. McGrew of the Field Museum of Natural History a detailed description is not given in this paper. In general the terminology used by Hill (2) is followed, since his descriptions place the foramina clearly, indicate their functions, and apply to the order Rodentia as a whole.

The *interpremaxillary foramina* as named by Hill (2) are present in all the genera studied excepting *Paleocastor*. They lie just back of the incisors on the palatal surface of the premaxillary lateral to the median suture. In *Castor* and *Eucastor* there is a single pair, but in *Castoroides* two pairs are present. In the three genera in which they occur the foramina are consistently very small.

The *incisive foramina* are invariably present as a pair of long, slender openings on the palatal surface of the premaxillary just anterior to the suture between the maxillary and premaxillary. The suture generally touches the posterior margins of the foramina.

The *posterior palatine foramina*, which transmit the palatine artery and nerve, are always present as a pair of small openings in the suture between the maxillary and palatine. They are very small in *Castor*, *Castoroides*, *Eucastor*, amd *Paleocastor milleri*. They are relatively large in *P. simplicidens* and *P. fosser*. There is considerable variation between individuals of a species in the size and shape of the foramina.

The *lateral posterior palatine foramina*, which transmit the palatine vein, are separated from the median foramina and lie back of M^3. They are present in all genera and are quite large.

The *infraorbital foramina* vary considerably in size and position in the four genera. In *Castor* they are quite small, and each passes forward from its posterior opening in the orbit near the base of the zygomatic arch to its anterior opening well down on the rostral part of the skull. A distinct shelf isolates each foramen from the area covered by the masseter major muscle. The condition in *Paleocastor* is quite different. The posterior opening is small and somewhat more dorsal than that of *Castor*. Traced forward, the infraorbital canal inclines dorsally to emerge in a long, narrow slit just anterior to the termination of the zygomatic arch in or just behind the maxillary-premaxillary suture. No shelf is developed to isolate the foramen from the masseter muscle, and all but the most ventral part of the opening appears to have been covered by the muscle (Stirton, 5). The condition in *Eucastor* is intermediate. The foramen on each side of the skull is more ventral than that in *Paleocastor* but less ventral than that in *Castor*. A partial shelf is developed separating the ventral part of the anterior

opening from the area covered by the masseter muscle; but dorsally this shelf is absent and the upper part of the foramen appears to have been covered by the muscle. In this respect *Eucastor* is nicely intermediate between the condition in *Paleocastor* and *Castor*, but the size of the foramen in *Eucastor* is relatively greater than that in the other two genera. The foramen in *Castoroides* is very small posteriorly and very large anteriorly. No shelf is developed, and it appears that the foramen was not only covered by the masseter muscle but was partly invaded by it.

The *nasolacrimal foramen* descends in all forms from the dorsoanterior angle of the orbit and passes into the nasal chamber. Little difference between genera has been observed.

The *anterior ethmoid foramen*, which transmits the anterior ethmoid nerve, is well developed in all forms studied. It lies in the suture between the frontal and orbitosphenoid anterodorsal to the optic foramen. The position is constant. The foramen is generally very small, particularly so in *Castoroides*, but in *Paleocastor milleri* it is relatively large, exceeding in size the optic foramen.

The *optic foramen* of the beavers is separate from the sphenoidal fissure but is always very small. Its position in the orbitosphenoid is constant. The foramen in *Eucastor* is larger than that in any other genus. In *Paleocastor* the optic foramen is very small, so small that it seems highly probable that the sense of sight was poorly developed.

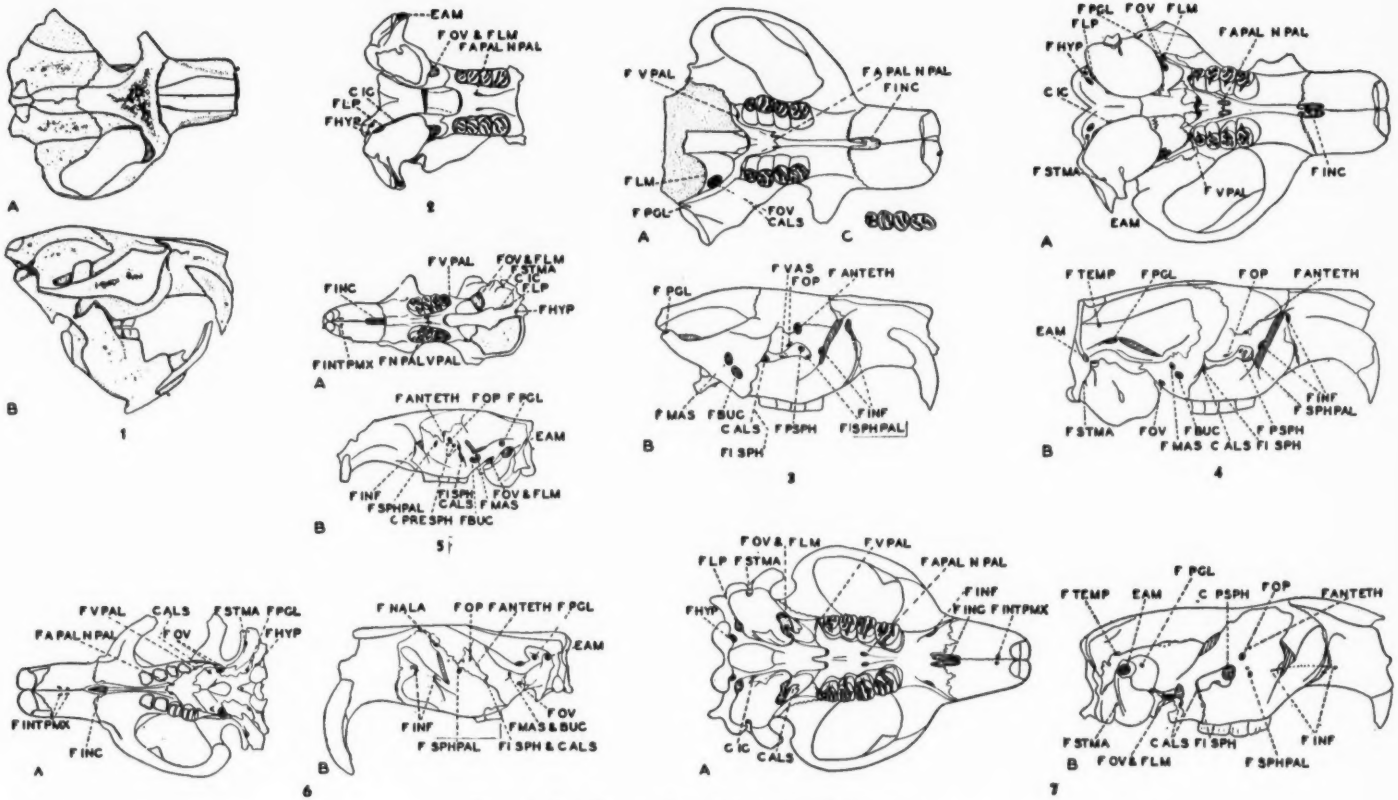
The *sphenopalatine foramen*, which transmits the sphenopalatine nerve and blood vessels, is well developed in the genera under consideration. It is very large in *Paleocastor*, well developed in *Castor*, and rather small in *Eucastor* and *Castoroides*.

The *presphenoid canal* is highly variable, more so than any other cranial opening. Because the sutures are poorly developed in the region of the canal in mature forms the relationships of the opening or openings to the adjacent elements is not always clear. In *Castor* the opening is usually a large, single canal passing between the orbits in the presphenoid. But there is much variation even within a single species. In some specimens of *Castor canadensis* the canal is divided into two or more parts by thin septae, and in a few specimens it is essentially absent. In *Castor* the canal lies at the anterior end of a deep sulcus, which passes back to the sphenoidal fissure. Lying below it is a somewhat variable foramen, which passes ventrally into the narial passage.

Castoroides, so far as the specimen examined is concerned, has but a very poor development of the presphenoid canal. It is represented by a single small opening, which passes in an arc to the opposite orbit and lies just ventral to the optic foramen. On one side of the specimen there is a second small canal, which appears to communicate with the passage of the larger canal within the presphenoid and which is probably a part of the presphenoid canal. No sulcus is developed in *Castoroides*. That the condition described from the one individual of *Castoroides* is typical of the genus is uncertain.

The condition in *Eucastor* is not entirely clear. Just anterior to the sphenoidal fissure on the left side of the skull is a large circular opening. Anterior to it is a small round foramen, and anterior to this, anteroventral to the optic foramen, is a third opening. These all appear to lie in the presphenoid, but the absence of sutures makes this uncertain. On the right side of the skull the large posterior opening is absent, but the anterior foramen is relatively large. No one of these foramina can be correlated definitely with any foramen in other beaver skulls, but the middle one on the left side of the skull lies close to the position usually occupied by the presphenoid canal in *Castor*. It seems probable that the three canals on the left side and the two on the right represent a system homologous to the presphenoid canal in other beavers. In *Paleocastor* the canal lies anteroventral to the optic foramen, and it is not unreasonable to assume that this may be the case, in part, in *Eucastor*. A serial arrangement of several foramina representing the canal sometimes occurs in *Castor*.

Paleocastor differs from all the other genera studied in having the presphenoid canal located entirely anterior to the optic foramen. Whether or not it lies entirely within the presphenoid bone cannot be determined



FIGS. 1–7.—For explanation see opposite page.

from the specimens at hand. In all specimens of *P. simplicidens* studied the canal was represented by a shallow fossa, at the bottom of which lay two or three small openings. A distinct groove passes forward to this fossa from the sphenoidal fissure much as in *Castor*. In the two specimens of *P. fosser* which show this area conditions are much the same. In *P. milleri* a single large canal is the only opening which belongs to the system. A deep sulcus is developed in this species as in the other two.

The *sphenoidal fissure* is constant in development and position and is always confluent with the anterior opening of the alisphenoid and sphenopterygoid canals. It lies between the alisphenoid and the orbitosphenoid, and part of the margin may be formed by the presphenoid. Ventrally the maxillary enters into the border. No significant differences have been noted between the various genera.

The *masticatory foramen* as named by Hill (2) carries a branch of the mandibular nerve. It is developed in the beavers as a rather large opening lying on the outer surface of the alisphenoid near the ventral margin of this bone. It is present in all the genera except *Castor*, where its absence is accounted for by the restricted development of the alisphenoid. In a few specimens of *Castor* the position of the masticatory foramen is indicated by a notch on the posterior margin of the alisphenoid. In *Castoroides* the masticatory and buccinator foramina are confluent. In *Eucastor* the foramen is large and lies nearly posterior to the buccinator. In *Paleocastor* the foramen is large and is separated from the buccinator foramen, to which it lies dorsal, by a narrow strip of bone. In one specimen of *P. simplicidens* the masticatory and buccinator foramina are confluent on one side of the skull and separate on the other. The opening of the masticatory foramen is very large in *P. milleri* and well developed but smaller in *P. simplicidens* and *P. fosser*.

The *buccinator foramen* in the various genera is similar in size to the masticatory foramen. Its position has been indicated in the preceding paragraph.

The *alisphenoid canal* is well developed in all of the genera studied, and there is relatively little variation in its structure or size. In all forms it passes forward from the deep pterygoid fossa to open anteriorly in common with the sphenoidal fissure. It is rather short in *Castor* and relatively long in the other three genera.

The *foramen ovale* of *Castor*, *Eucastor*, and *Castoroides* lies between the alisphenoid and the tympanic bulla in the pterygoid fossa and is confluent with the foramen lacerum medium. The same condition is found in most specimens of *Paleocastor*, but in one specimen of *P. milleri* and one of *P. fosser* the alisphenoid forms a bar back of the foramen ovale isolating it from contact with the tympanic bulla and the foramen lacerum medium. In the other specimens of these species of *Paleocastor* and in *P. simplicidens* the condition is like that found in the other genera.

In *Castoroides*, *P. fosser*, *P. simplicidens*, and the paratype of *P. milleri* a well developed foramen is present in the alisphe-

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EXPLANATION OF FIGURES 1–7

FIGS. *1–3*.—*Paleocastor milleri* Olson, n. sp. *1*, Dorsal and lateral aspects of holotype, Walker Mus. 1582. ×⅔. *2*, Ventral aspects of paratype, Walker Mus. 1583. *3*, Ventral and lateral aspects of holotype.

4—*Paleocastor simplicidens* (Matthew). Ventral and lateral aspects of Walker Mus. 1461.

5—*Eucator tortus* Leidy. Ventral and lateral aspects of Field Mus. P15787.

6—*Castoroides ohioensis* Foster. Ventral and lateral aspects of Field Mus. specimen.

7—*Castor canadensis* Kuhl. Ventral and lateral aspects of the specimen in the Walker Mus. osteological collections.

C ALS, Alisphenoid canal; C IC, internal carotid canal; C PRESPH, presphenoid canal; E A M, external auditory meatus; F A PAL N PAL, posterior palatine foramen; F ANTETH, anterior, ethmoid foramen; F BUC, buccinator foramen; F HYP hypoglossal foramen; F INC, incisive foramen; F INF, infraorbital foramen; F INTPMX, interpremaxillary foramen; F L M, median lacerate foramen; F L P, posterior lacerate foramen; F MAS, masseteric foramen; F NALA, nasolachrymal foramen; F OP, optic foramen; F OV, foramen ovale; F PGL, postglenoid foramen; FI SPH, sphenoidal fissure; F SPHPAL, sphenopalatine foramen; F STMA, stylomastoid foramen; F TEMP, temporal foramen; F V PAL, lateral posterior palatine foramen.

noid, which forms the lateral wall of the pterygoid fossa. This leads into the alisphenoid from the opening of the foramen ovale in the pterygoid fossa and appears to be a continuation of it. The foramen is not developed in *Castor*, since the alisphenoid does not extend back to the level at which it might be present. There is no evidence of the foramen in *Eucastor* although the alisphenoid is continued posteriorly to the tympanic bulla.

The position of the opening of the foramen ovale into the fossa from the cranial cavity is somewhat variable. It is at the lateral margin of the fossa in *Paleocastor*, particularly so in *P. fosser*, and *Castoroides*. It is somewhat more medial in *Eucastor* and *Castor*.

The *canal* for the *internal carotid* is constant in position in all the forms studied. It lies between the tympanic bulla and the basisphenoid, its lateral walls being formed by these two elements. The dorsal and ventral walls are formed by the tympanic bulla. It has not been possible to follow the canal into the cranial cavity in any form except *Castor*. In this genus it continues forward into the basisphenoid, which it penetrates for a short distance before entering the cranial cavity.

The *foramen lacerum posterius* lies between the tympanic bulla and the basioccipital, most of its margin being formed by the bulla. It is very small in all the genera studied, and no marked differences are apparent.

The *foramen* for the *stapedial artery* has not been identified in any of the forms studied.

The *hypoglossal foramen* lies in the basioccipital just anterior to the condyle. There is usually a single opening in *Castor*, but in a few specimens of the series examined two are present. Two foramina occur in all of the specimens of *Paleocastor* which were studied. The specimens of *Eucastor* and *Castoroides* have a single opening.

The *stylomastoid foramen* is strongly developed in all the beavers studied. It lies at the junction of the tympanic bulla and the mastoid along the lateroposterior margin of the bulla. No marked differences have been noted in the various genera.

The *external auditory meatus* always lies well above the body of the bulla. In *Paleocastor* it is directed laterally, but in *Eucastor* and *Castor* it opens more dorsally. The meatus in *Castoroides* is more lateral than that in *Castor* but less so than that in *Paleocastor*.

The *foramen magnum* shows only slight proportional differences in the various genera.

The *postglenoid foramen* is constant in position but tends to vary considerably in size. It is small in *Paleocastor*, large in *Eucastor* and *Castoroides*, and intermediate in *Castor*. It lies in the squamosal just back of the termination of the zygomatic arch.

The *temporal foramina*, which are vascular in nature, vary markedly. When present they lie along the parietal-squamosal suture or just to one side of the suture in either the parietal or the squamosal. As a rule the temporal foramina are not developed in *Paleocastor*, but one may be present in the posterior part of the squamosal. *Eucastor* has a single small opening at the level of the external auditory meatus. *Castor* has one or two openings in the same region, while *Castoroides* has several along the suture with several large openings opposite the posterior termination of the zygomatic arch.

The *subsquamosal foramen* has been identified only in *Castor* and *Castoroides*. It lies between the squamosal and mastoid along the posterior margin of the former near the termination of the lambdoidal crest. Its absence in other genera is probably caused by faulty preservation rather than by actual lack of development of the foramen.

The *mastoid foramen* is present on the occiput of all the forms studied except the paratype of *P. milleri*. Its absence in this form is probably a result of poor preservation of the area in which it might be expected. In *Castor* and *Castoroides* it lies between the mastoid and the occipital at the dorsomedian corner of the former. Its exact relationship to the two bones in *Eucastor* is uncertain because of the damaged condition of the occiput of the specimen studied. In *Paleocastor simplicidens* the foramen is entirely surrounded by the mastoid, while in *P. fosser* the condition appears to be like that in *Castor*.

There are many *vascular foramina* present

in all the skulls studies, the greatest number being developed in *Castoroides*. They are extremely variable, often being developed on one side of a particular skull and not on the other. No attempt has been made to correlate or name these openings.

DISCUSSION

This paper will not consider at much length the validity and usefulness of cranial foramina in the separation of species or genera or in the determination of phylogenetic relationships, since this will be dealt with using more suitable material in a paper now in preparation by the writer and Mr. Charles Sternberg of Walker Museum. A few points of interest, however, become apparent from the present study. These are summarized as follows:

1. About 30 per cent of the cranial foramina in the family Castoridae show no appreciable changes in the four genera studied. Another 30 per cent show no greater changes between genera than occur within a single genus. Eight per cent show marked changes with increase in skull size but are not of phylogenetic significance. Hence nearly 70 per cent of the foramina are not subject to evolutionary changes of significant amounts and are of little or no value in differentiating genera and species of the family. They indicate, rather, a marked stability of the cranial foramina within the Family Castoridae.

2. Comparisons of the cranial foramina of the beavers with those in other families of rodents indicate clearly that the arrangement in the family Castoridae is distinctive and does not occur in any other family.

3. About 27 per cent of the foramina show changes between genera which appear to be evolutionary in nature and are sufficiently large to be useful. The foramina showing such changes are: the infraorbital foramen, the presphenoidal canal, the foramen ovale, the external auditory meatus, the optic foramen, the sphenopalatine foramen, and the interpremaxillary foramen.

Comparisons of the conditions in the first four indicate that *Eucastor* is closer to *Castor* than to *Castoroides*. This is in conflict with the conclusions of Stirton (5), based principally on dental characters, that *Eucastor* is on or close to the line leading to *Castoroides*. It agrees more closely with the conclusions of Schreuder (4). The optic foramen is much reduced in *Paleocastor*. There seems to be a specialization which bars *Paleocastor* from direct ancestry to the later genera. It is the only feature of the cranial foramina which would appear to place *Paleocastor* on a sterile side branch. The condition of the sphenopalatine foramen of *Eucastor* is more similar to that of *Castoroides* than that of *Castor*. It is possible that the condition is *Castor* could have been derived from that in *Eucastor*, but it seems improbable. From what evidence there is on the foramina it seems that *Eucastor* lies close to the line of *Castor* but is not directly ancestral. The interpremaxillary is present in all but *Paleocastor*. Although this difference appears to be evolutionary in nature its meaning will not be clear until it is established whether the presence of the foramen is a primitive or specialized character. This cannot be done from the material available.

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JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 5, PP. 502–504, 2 TEXT FIGS., SEPTEMBER, 1940

SPHAEROSPONGIA IN THE TULLY FORMATION

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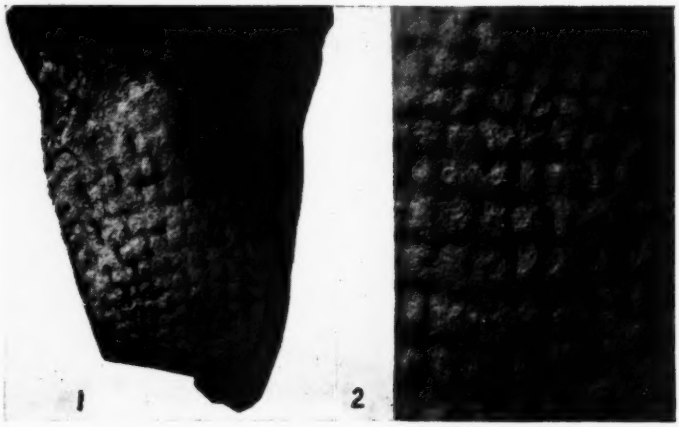
ABSTRACT—A specimen of the receptaculitid sponge *Sphaerospongia* from the Tully formation of central New York is referred to the type species, *S. tessellata* (Phillips). This species occurs elsewhere in the *Stringocephalus* zone (Givetian) of Devonshire and Manitoba. It is suggested that the Tully may be the correlative of the *Stringocephalus* zone.

THE list of the fossils of the Tully formation (Devonian of central New York) by Cooper and Williams (1935, p. 855), includes *Receptaculites?* sp. This was on the basis of a determination by the writer of a specimen collected by him in 1930. The specimen is poorly preserved and represents an internal mould of some receptaculitid sponge. The sponge itself was largely replaced by platy barite and iron minerals, which destroyed practically all traces of finer structure. On more recent examination, however, some faint structures were observed which indicate that it is a *Sphaerospongia* resembling *S. tessellata* (Phillips).

The specimen was collected from the upper beds of the Tully limestone near the top of a small waterfall in a ravine about 2 miles southwest by south of Fabius, Onondaga County, New York. The growth form is not wholly shown, but there remains an irregular cone, flaring towards the top, basally cornute, 42 mm. high, 30 mm. in diameter in the middle (fig. 1). There is no trace of the rounded summit or basal termination. Most of the specimen shows only a mould of the interior, which appears as a reticulum formed by longitudinal and transverse grooves averaging about 1 mm. in width. The longitudinal grooves are about 1.5 mm. apart; the transverse, 1.5 to 2.5 mm. They are the impressions of the interlocking cruciform "spicules" (fig. 2) that underlie the hexagonal plates of the outer surface, and their arrangement is the same as that described and figured by Whiteaves (1892, p. 261, pl. 33, f. 1a); " . . . the distal ray of each 'spicule' passes behind or inside of the proximal ray of the 'spicule' immediately above it." The length of the proximal rays is 3 mm. measured from the center of the "spicule"; the width between tips of the lateral rays about 4.5 mm. In thickness the rays average 1.0 mm. There is no evidence



FIGS. 1, 2.—*Sphaerospongia* cf. *S. tessellata* (Phillips), Tully limestone, Onondaga County, New York. *1*, ×1; *2*, part of surface of same specimen as *1*, showing impressions of several cruciform spicules, ×3.

of a vertical ray. Only the faintest traces of the overlying hexagonal plates are shown, but from the dimensions of the "spicules" they were elongate-hexagonal in shape, from 2.5 to 3.0 mm. in diameter.

This specimen is certainly very close to, if not identical with the *Sphaerospongia tessellata* described by Whiteaves from the Winnepegosan limestone (*Stringocephalus* zone) of Dawson Bay, Lake Winnepegosis, Manitoba (1892, pp. 259–263, pl. 33). The form of the two cannot be well compared, for the Tully specimen is incomplete, and the Manitoban specimens show much individual variation away from the presumably normal pyriform shape. The size of the "spicules" in the Canadian form is stated to be 3.5 mm. for the proximal rays, 5.5 mm. for the laterals, and 0.9 mm. in thickness, in the same region of the sponge as the corresponding elements of the Tully specimen. The plates of the Canadian specimen are 4.0 mm. in diameter centrally.

Specimens of *S. tessellata* (Phillips), 1841, from the Torquay limestones in the type region around Torquay, Southern Devonshire, based on measurements of Hinde's figures (1884, pl. 37, f. 1), possess "spicules" measuring 2.33 mm. for the proximal rays, 6 mm. across the laterals, 1 mm. in thickness. The plates vary from 0.5 to 7.5 mm. in diameter, averaging 4.0 mm. centrally.

S. cornucopiae (Goldfuss), of the Middle Devonian of the Eifel region, differs, according to Schlüter (1887, pp. 13-14, pl. 1, f. 1, 2), from *S. tessellata* by its smaller plates, which are never more than 2.8 mm. in diameter. The German species was considered identical with *S. tessellata* by Whiteaves, but from measurements of Schlüter's figures, as indicated below, it is probably distinct.

On the basis of only the "spicules" and approximate size of the plates there is insufficient evidence to show that the New York specimen is specifically distinct from the Manitoban, or further that these two are distinct from the Devonshire form. On the other hand all are quite distinct from the other species ascribed to *Sphaerospongia* from the Middle Devonian of Europe (except perhaps the *S. tessellata* figured from the Devonian of the Urals by de Verneuil in 1846). A comparison of the dimensions of the New York, Manitoba, and Devonshire specimens of *S. tessellata* and *S. cornucopiae* is shown in the table.

The horizon of *S. tessellata* in its type region is uncertain. The decribed specimens all appear to have come from the Torquay limestone at several different localities near Torquay, namely, St. Mary Church (Broderip), Newton Bushell (Hinde), Lummaton (Whidbourne), Woolborough quarry near Newton Abbott (Pengelly). These limestones are in part upper Middle Devonian (Givetian) and in part lower Upper Devonian (Frasnian), but thus far it has been impractical to draw a boundary between the Middle and Upper Devonian in the Torquay and Plymouth areas (Jukes-Browne, 1906; Shannon, 1928, pp. 112–113; Evans and Stubblefield, 1929, pp. 130–131; Ussher, 1933, p. 76). However, according to Dr. Stanley Smith (*in litt.*) *Sphaerospongia tessellata* occurs at the Lummaton quarry in beds of Givetian age. This is the only definite information available to the writer regarding the horizon of this species in Devonshire, and it seems fair to assume that there it is probably confined to the *Stringocephalus* zone (Givetian).

The age of the Tully—whether Middle or Upper Devonian—cannot yet be said to be settled, although the Tully is customarily regarded as belonging to the lower part of the Upper Devonian system in New York,

DIMENSIONS OF SPHAEROSPONGIAS (MILLIMETERS)

	New York	Manitoba	Devonshire	Eifel
	cf. *tessellata*	*tessellata*		*cornucopiae*
Diam. of plates	ca. 2.5–3	4	4	2.8
Proximal rays	3.0	3.5	2.3	2–2.5
Lateral rays	4.5	5.5	6.0	4
Thickness of rays	1.0	0.9	1.0	0.4

principally because of the occurrence in it of *Hypothyridina* and *Scutellum*, exotic types not found below in the New York Hamilton. Cooper and Williams (1935, p. 824), however, have noted that the great preponderance of Hamilton species and derivatives in the Tully suggests its Middle Devonian affinities. The occurrence described above of *Sphaerospongia*, another exotic form confined elsewhere to the Middle Devonian, especially to the *Stringocephalus* zone, though admittedly not conclusive, certainly tends to confirm this view. The writer would submit further that the Tully is probably homotaxial with, if not indeed the correlative of the *Stringocephalus* zone of Europe and the western United States and Canada.

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TWO NEW CYPRAEAS FROM COSTA RICA

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TWO new cowries, named here *Cypraea costaricaensis* and *Cypraea cinerea* var. *limonensis*, have been found in the United States National Museum's collections from Costa Rica. They were collected in 1911 by Donald MacDonald near the town of Limon, and are apparently a part of the Pliocene fauna said by Woodring (1928) to be the largest fauna of this age thus far attributed to the Caribbean region.

Few fossil Cypraeidae have been reported from the Pliocene of Costa Rica. Gabb (1874–81) listed two species, *Cypraea cinerea* Gmelin and *Cypraea carneola* Linnaeus, from the Pliocene beds. Ingram (1939a) described *Cypraea bartschi* and *Cypraea cinerea* var. *morinis* from the Pliocene of Moen Hill, where specimens were taken from a railroad cut two and one-half miles outside Limon, Costa Rica. The holotype specimens of these Cypraeidae were collected in 1917 by Dr. W. P. Woodring, and are now in the United States National Museum.

CYPRAEA COSTARICAENSIS
Ingram, n. sp.
Figures 1, 2

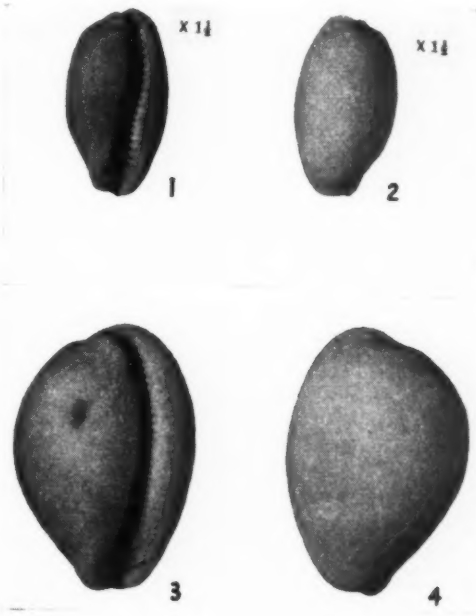
Shell cylindrically oblong; light; anterior canal marginated dorsally by an impression; outer lip of posterior canal projects, and is also marginated dorsally by an impression; anterior canal produced, about 4 mm. broad; base convex; aperture nearly straight, widest anteriorly; teeth on both lips confined to aperture, except central columellar ones which extend a short distance over the base; teeth fine, of about equal length; posterior columellar teeth extend but a short distance on columella; incisures shallow, narrow; spire depressed, leaving a very noticeable indentation just dorsal to the posterior canal.

Dimensions: Length 16.50 mm., breadth 9.95 mm., height 8 mm.

Holotype: U. S. Nat. Mus. 498,682.

Type locality: Second bed from top of Moen Hill, Costa Rica, U. S. Nat. Mus. locality 5884b. Pliocene.

This species is distinct from all others from the Americas and the West Indies which have been described in the fossil state. The spire is umbilicate, much resembling that



FIGS. 1, 2.—*Cypraea costaricaensis* Ingram, n. sp. Holotype, U. S. Nat. Mus. 498,682, ×1½.
3, 4.—*Cypraea cinerea* var. *limonensis* Ingram, n. var. Holotype, U. S. Nat. Mus. 498,683, ×1.

of the living species *Cypraea punctulata* Gmelin (not *C. punctulata* Gray).

CYPRAEA CINEREA var. LIMONENSIS
Ingram, n. var.
Figures 3, 4

Shell bulbous, sloping into anterior and posterior canals; spire depressed; base rounded; canals short, anterior one produced but slightly; teeth confined to aperture; teeth fine and of about equal width on columellar and outer lips, interstices wider

on columellar than on outer lip; columellar interstices fairly flat, those on the outer lip rounded; aperture wider anteriorly than posteriorly; aperture narrowest in middle.

Dimensions: Length, 35.25 mm.; breadth, 24.10 mm.; height, 21.75 mm.

Holotype: U. S. Nat. Mus. 498,683.

Type locality: Lowest bed in street cut on the outskirts of Limon, Costa Rica, U. S. Nat. Mus. locality 5885d. Pliocene.

This variety differs from the typical *Cypraea cinerea* Gmelin in having the teeth confined to the aperture; in having a broader anterior canal; and in the lack of the production of the posterior canal. The shell is more bulbous than that of any Recent individuals of this species.

Cypraea cinerea Gmelin has quite an extended range in the fossil state. It has been reported from the Miocene of Santo Domingo by Pilsbry (1921) and by Ingram (1939b), and from the Miocene of Costa Rica by Olsson (1922). Dall (1905) reports it from the Pliocene of Bermuda. A species that apparently shows close relationship to *C. cinerea* Gmelin is *Cypraea dominicensis* Gabb, a Miocene species, from Santo Domingo, Costa Rica, and from Panama.

Grateful acknowledgment is made to the late Dr. W. C. Mansfield of the United States Geological Survey for stratigraphic information concerning the two species described. Appreciation for advice rendered is due Dr. C. W. Merriam of the Department of Paleontology of Cornell University. The writer wishes to thank Dr. Paul Bartsch, Dr. Harald Rehder, and Mr. F. S. MacNeil, who allowed him to examine the specimens in the United States National Museum. The photographs were made by Mr. N. W. Shupe of the United States Geological Survey.

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SUPPLEMENTARY NOTES ON THE OCCURRENCE OF TERTIARY NOETINAE

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THIS paper is intended to supplement my paper on "Species and genera of Tertiary Noetinae" (MacNeil 1938).

Field work with W. C. Mansfield in the spring of 1938 enabled the writer to examine further some of the *Eontia*-bearing beds of Florida and to make additional collections and notes on the stratigraphic occurrence of Floridian species. These notes deal specifically with forms collected from the typical Caloosahatchee marl of Pliocene age in the vicinity of Denaud, Hendry County; from the Pleistocene deposists at Buffalo Bluff, Putnam County, 1.6 miles northwest of Murdock, Charlotte County, and at the Charlotte County Stockade, 2 miles northeast of Punta Gorda, Charlotte County.

Dall's original description of *Arca limula platyura* stated that it occurred in the "Pliocene of the Caloosahatchee and Alligator Creek." Because of inadequate material and locality information, the specimens labelled "Caloosahatchee beds" were ignored in the writer's previous paper, and the lectotype was selected from a collection from Alligator Creek at Acline.

A section observed along the left bank of the Caloosahatchee River at the Walker farm, three-quarters of a mile above Denaud, which may have been one of Dall's localities, was recently described by Mansfield (1939 a). The bank of the river at this point was found to be divisible into two well-defined mollusk-bearing beds referable to the Caloosahatchee marl: a lower, 3-foot bed containing an abundance of fresh-water gastropods and mussels in addition to marine species, and a higher 5- to 7-foot bed containing fewer fresh-water shells and no mussels, but containing a richer and more varied marine fauna. Underlying these beds is exposed about 1 foot of a sticky buff clay, which may also be of Caloosahatchee age. The lower fossiliferous bed, the mussel-bearing bed, yielded one incomplete specimen of *Eontia*, which compares well with specimens of *E. platyura* from Alligator Creek. The upper bed in this vicinity, however, and the spoil bank along the canal, yielded several specimens very definitely referable to *E. variabilis* and resembling closely specimens from the upper horizon 6 miles northwest of Clewiston and others from North Carolina. Some specimens approach the variety *E. variabilis quadrata*, described from Walker's Bluff on the Cape Fear River, North Carolina. No emphasis is placed on the incomplete specimen from the lower bed, the identification of which is uncertain. The well-preserved specimens of *E. variabilis*, however, show clearly that they are not the species occurring at Alligator Creek, and also lend strong support to the writer's contentions that during Pliocene time the *E. variabilis* stock from the east and north invaded south-central Florida, and that this species was well established in at least the upper part of the typical Caloosahatchee marl.

Although *E. platyura* is regarded as the indigenous species in this region, it is identifiable with certainty only on the west coast at the Alligator and Shell Creek localities, which, following Dall, have generally been assigned to a somewhat higher stratigraphic horizon than the Caloosahatchee marl along the Caloosahatchee River near Labelle. If this correlation is correct, the survival of *E. platyura* on the west coast is best explained by inferring the existence of a land barrier in the form of a ridge of Miocene limestone extending in a roughly north-south direction between Floweree and Buckingham. To this limestone Mansfield (1939, *b*) has given the formational name Buckingham limestone. That this limestone promontory was land is evidenced by the presence of land and fresh-water shells mixed with marine shells along its flanks, and by the fact that no Pliocene marl is found to overlie it between the points named along the Caloosahatchee River. The faunal differences on which the interpretation of a difference in age between the deposits on the Caloosahatchee River

and Alligator Creek is based may be due, however, merely to the existence of contemporaneous east- and west-coast faunas rather than to any actual difference in the time of deposition. Further study of a specimen collected from a marl pit north of Bermont has convinced me that it is *E. platyura* and not *E. variabilis*, to which it was doubtfully referred. The three localities from which *E. platyura* has been obtained thus fall in a relatively small area and probably represent an embayment from the Gulf side.

Specimens from 1.6 miles northwest of Murdock, Charlotte County, Florida, which in the previous report were identified as *E. ponderosa* (Murdock form) and were believed to be Pliocene because of their association with Pliocene species, are now known to be Pleistocene. The locality at Murdock was revisited, and it was found that the material obtained from the ditch at this locality is a mixture of Pliocene and Pleistocene specimens. The Murdock locality is in the vicinity of the Myacca River, deposits along which Dall referred to a very high Pliocene horizon on the basis of the percentage of Recent species rather than on any particular characteristic species. It now appears that the material in Dall's hands was obtained in the same way as the collection made by W. C. Mansfield and the writer and contains a small percentage of Pliocene material obtained from a lower horizon mixed with a larger percentage of Pleistocene material. The same typical form of *Eontia ponderosa* was obtained from the extensive pits at the Charlotte County Stockade, 2 miles northeast of Punta Gorda, associated with a typical Pleistocene fauna.

At Buffalo Bluff on the St. Johns River, Putnam County, Florida, a series of specimens was collected that cannot be separated from Pleistocene forms occurring at Green Cove Springs in Clay County, or on the north shore of Lake Monroe, Volusia County. Shells from this region are generally smaller than those from the region of Myrtle Beach, South Carolina, but appear to duplicate the varieties found in that region. These shells are referred to *E. ponderosa*, but, as previously stated, are more varied and less truncate than the Recent forms.

The forms from a locality just south of the airport at De Leon Springs, Volusia County, Florida, doubtfully referred by me to *E. variabilis*, are very similar to those from Buffalo Bluff. The De Leon Springs horizon was regarded by Mansfield (1939, *c*) as high in the Pliocene, and the similarity of the Eontias from there to those from Buffalo Bluff, which he regarded as low Pleistocene, substantiates this age assignment. If anything, the De Leon Springs forms are most like the early *ponderosa* stock of the Atlantic coast Pleistocene, but it remains a matter of opinion as to whether they should be referred to *E. variabilis* or *E. ponderosa*. I do not agree with Mansfield (1939, *d*) in referring them to *E. platyura*, although he states that they "show a gradation toward *E. variabilis*."

I believed at the time Professional Paper 189-A was being written that *E. platyura* might have contributed to the composition of the late Pliocene series of the Atlantic coast, but I now think it is certain that *E. platyura* is a typically west-coast species, and that its influence on the east-coast series was not felt until Pleistocene time.

A recent examination of the Robert T. Hill collection from Vamos-a-Vamos (a cut along the Panama Canal about 12 miles south of Colon) revealed four specimens of a species closely related to *Arca* (*Argina*) *samanensis* Olssen, a species described from the Saman formation, of upper Eocene age, of Peru. The beds at Vamos-a-Vamos have been variously assigned to the Eocene, Oligocene, and Miocene. Dall (1898) originally regarded the Vamos-a-Vamos beds as of Claiborne age, but Woodring later correlated them with the Cercado formation of the Dominican Republic and assigned them to the early middle Miocene. In a more recent, unpublished, chart Woodring places the Vamos-a-Vamos beds in the upper Oligocene. The species in the Vamos-a-Vamos beds may prove to be more closely related to, if not identical with *Arca* (*Agina*) *puntabravoensis* Olsson, a species described from the Punta Bravo grits, of supposed Oligocene age, of Peru, but as there are no specimens of the latter in the National Museum I cannot be certain. This note at least serves to put its occurrence on record.

For *Arca* (*Argina*) *samanensis* Olsson I

proposed the generic name *Arginella*, which, unfortunately, proves to be preoccupied in Hymenoptera by *Arginella* Forsius, 1926, new name for *Argina* Forsius, 1925. For *Arginella* MacNeil I substitute *Samanoetia*.

Three months after the publication of Professional Paper 189-A, Caster (1938) described a new species from the Eocene at the mouth of the Luculo River, near the village of Quimbriz, Angola, as *Arca* (*Noetia*) *veatchi* Caster. This name proved to be a homonym and was replaced by *Arca* (*Noetia*) *veatchites* Caster (1939). As pointed out by Caster, this species is related to *Protonoetia nigeriensis* (Newton), which he also reports from the Angola locality, but differs in being considerably larger, with a shorter hinge line and fewer teeth, and in lacking the radial lines of "elongate tubercles on the post-umbonal surface," which in my terminology are referred to as beaded interstitial ribs. The fact that the beaks of *Arca veatchites* are definitely opisthogyrate is sufficient to mark it as a true *Noetia*, but it is certainly one of the border-line species between *Noetia* and *Protonoetia*, which is characterized by orthogyrate beaks. The extent to which the ligament occupies the posterior part of the cardinal area shows its relationship to *Protonoetia*. It also compares in this respect with *Noetia nagaoi* MacNeil from the upper Eocene of Japan.

One more nomenclatorial change remains to be emphasized. Iredale (1939) pointed out that *Paranoetia* Thiele, 1934, is an absolute synonym of *Barbatiella* "Jousseaume" Lamy, February 1917 (type, *B. barbatiella* "Jousseaume" Lamy) (=*Arca lateralis* Reeve, fide Lamy), a Jousseaume manuscript name which Lamy published together with Jousseaume's description, but declined to accept, but which gained status nevertheless. I treated *Paranoetia* as a subgenus of *Sheldonella* Maury, April 1917, but since Jousseaume's name has two months priority, it must become the genus with *Sheldonella* the subgenus. There is doubt in my mind as to whether *B. barbatiella*, from Djibouti, is identical with *Arca lateralis*, described from the Philippines. I delimited the Indian ocean and Indo-Pacific forms into the eastern species, *A. lateralis*, and the west Indian Ocean species, *Barbatia cafria* Bartsch, described from South Africa. Iredale has further separated the Australian form from *A. lateralis* as *Barbatiella venustopsis* Iredale. *Barbatia cafria* was reported from South Africa to the Red Sea and the west coast of India, but unless some difference can be found between the northern and southern forms, it appears that *Barbatiella barbatiella* is an older name for this species.

Opportunity is here taken to point out two errors in Geological Survey Professional Paper 189-A. Dr. A. A. Olsson has called to my attention the fact that I misquoted him on page 38 as saying that the Mancora Tablazo beds of Peru are of Pleistocene age. Dr. Olsson regards the Mancora Tablazo as of Pliocene age. Also page 1, col. 2, line 17 should read, "Florida Geological Survey," not "Florida State Museum."

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PLIOCENE MOLLUSKS FROM A WELL AT SANFORD, FLORIDA

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ABSTRACT—Eighty-seven species of mollusks recovered from a depth of 85 to 95 feet at Sanford, Fla., represent the facies of the Caloosahatchee marl formerly called Nashua marl, which crops out in the adjoining county on the north but lies far north of the nearest exposure of the typical Caloosahatchee.

IN DECEMBER, 1937, Mr. H. James Gut of Sanford, Seminole County, Fla., supplied me with a box of shells obtained from the City of Sanford municipal supply well no. 5. That same month I visited the well and obtained additional specimens.

The well was drilled about 1927, and at that time it was equipped with an air-lift pump. In November, 1937, pumps of this type were removed from all the city wells, and deep-well cylinders were installed. The superintendent of the water plant informed me that when he pulled the 90-foot drop pipe in well no. 5 he found that about four feet of the pipe had been buried in mud. Hoping to clean out the well, he replaced the drop pipe to about 85 feet and turned compressed air into the well, with a resulting volcano of mud and shell. Several cubic yards of material were forced from the well before efforts to clean it by means of compressed air were abandoned. In the spring of 1938, a well driller cleaned out this well and drove the casing an additional 9 feet before seating it in the limestone.

From the above information, I infer that the casing was probably seated in the sandy shell marl at a depth of about 90 feet, and that this marl eventually caved in between the bottom of the casing and the limestone upon which it lies. This being true, the shells herein listed probably all came from 85 to 95 feet below the surface. The surface elevation at this well is approximately 45 feet above mean sea level.

The shells recovered from this well, which are enumerated in the following list, are of interest because there are no surface exposures of fossiliferous beds in this county, and because well cuttings usually yield a poorly preserved and meagre fauna. Beautifully preserved specimens of large and fragile species were obtained from this well. The occurrence of the species at other Florida Pliocene localities has been determined by a study of collections in the United States National Museum, for permission to examine which I am indebted to the late Dr. W. C. Mansfield of the U. S. Geological Survey and to Dr. Paul Bartsch of the Division of Mollusks of the Museum. The occurrence of the species in the Choctawhatchee Miocene has been ascertained by reference to Mansfield's (1930, 1932), papers on the fauna of the Choctawhatchee formation. The occurrence of species in the recent fauna has been determined by reference to Dall's (1889) catalogue and Johnson's (1934) list.

Although the species of Gasteropoda and Pelecypoda represented in the well are nearly equal in number, the Pelecypoda greatly outnumber the Gasteropoda in individuals. Many of the latter are represented by single individuals, but most of the former are abundant.

The genus *Terebra* is represented by three distinct species, but only *T. dislocata* Say is common. This and *Oliva sayana* Ravenel are represented by the greatest number of individuals of all the Gasteropoda. The two species of *Olivella* are both common, being represented by numerous individuals. *Fasciolaria apicina* Dall is common. *F. gigantea* Kiener is represented by only two young specimens. The genus *Busycon* is represented by five species, and each species by several individuals. *Anachis obesa* C. B. Adams, var., is common in this well, as it is also at DeLeon Springs. The genus *Crepidula* is represented by five species, and each species by several individuals. *Turbo crenulatus* Gmelin is common. The genus *Turritella*, which is plentiful in the Pliocene of the Caloosahatchee and Shell Creek, is represented at Sanford by one specimen,

MOLLUSKS FROM WELL AT SANFORD

Pelecypoda:	Choctawhatchee formation	Recent fauna	Nashua	DeLeon Springs	DeLand	Orange City	Caloosahatchee River	Shell Creek
Nucula proxima Say	×	××		××	××		××	×
proxima var. *trunculus* Dall		××		××	××		××	
Eontia variabilis MacNeil				×	×			
variabilis quadrata MacNeil								
platyura (Dall)?								
Arca (*Scapharca*) *alcima* Dall				×			×	
(*Scapharca*) *plicatura* Conrad				×	?			
(*Scapharca*) *subsinuata* Conrad				×			?	?
Glycymeris americana (DeFrance)	×	×		×			×	
Ostrea sculpturata Conrad	×		?	×	×	×	×	×
virginica Gmelin		×	×	×	×	×	×	
sp., young								
Pecten gibbus Linné		×		×				
eboreus var. *solaroides* Heilprin			×	×	×	×	×	×
Spondylus sp., young								
Anomia simplex d'Orbigny	×	×	×	×	×		×	
Mytilus exustus Linné		×					×	×
Cardita arata (Conrad)	×			×		×	×	×
Venericardia tridenta Say		×		×	×	×	×	
Chama striata Emmons	×						×	×
Divaricella quadrisulcata (d'Orbigny)	×	×	×		×			
near *quadrisulcata* (d'Orbigny)								
Phacoides anodonta (Say)	×			×			×	×
trisulcatus (Conrad)		×	×	?			×	×
radians (Conrad)		×		×	×		×	×
multilineatus (Tuomey and Holmes)	×	×	×	×	×	×	×	×
waccamawensis Dall			×	×			×	×
waccamawensis delandensis Mansfield				×	×	×	?	
Taras acclinis (Conrad)	×			×	×		×	
Cardium isocardia Linné		×		×			×	
robustum Solander	×	×		×			×	×
Dosinia elegans Conrad	×	×	?	×	?		×	×
discus Reeve		×		×			×	×
Venus rileyi Conrad	×			×	×		×	×
Chione cancellata (Linné)		×	×	×			×	×
athleta (Conrad)	×	×		×	×		×	×
Macrocallista nimbosa Solander		×		×			×	×
Callocardia sayana (Conrad)	×						×	
Gafrarium metastriatum (Conrad)	×		×	×	×	×	×	×
Gemma magna Dall	×		×	×			×	×
trigona Dall				?			×	
trigona delandensis Mansfield				?	×	×		
Petricola sp.								
Tellina alternata Say	×	×					×	×
Tellidora cristata (Recluz)		×					×	×
Abra aequalis Say	×	×		×	×		×	
Tagelus divisus Spengler	×	×					×	×
Mulinia lateralis Say, long form of Mansfield		?	?	×	×	×	?	?
lateralis Say, heavy form of Mansfield		?		×	×		?	?
contracta (Conrad)				×	×			
congesta (Conrad)	×			×				
Rangia cf. *R. cyrenoides* Desmoulins								
Corbula caloosae Dall, var.								
inaequalis Say	×			×				
inaequalis Say, var.								
barrattiana C. B. Adams	?	×	×	×			×	×
Gastrochaena cuneiformis Spengler?								

MOLLUSKS FROM WELL AT SANFORD—*Continued*

Gasteropoda:	Choctawhatchee formation	Recent fauna	Nashua	DeLeon Springs	DeLand	Orange City	Caloosahatchee River	Shell Creek
Acteocina canaliculata (Say)	×	×		×			×	×
Terebra concava Say		×	×	×	×	×	×	×
near *concava* Say								
protexta Conrad	?	×		×			×	×
dislocata Say	×	×	×	×	×		×	×
Cymatosyrinx limatula (Conrad), var.								
Drillia tuberculata Emmons				×	×			
Cancellaria conradiana Dall		×					×	×
tenera Philippi	×	×					×	×
Oliva sayana Ravenel	×	×	×	×	×	×	×	×
Olivella mutica Say	×	×	×	×			×	×
nitidula Dillwyn					×	×	×	×
Marginella limatula Conrad		×	×		×		×	×
bella Conrad		×			×		×	
near *bella* Conrad								
near *apicina* Menke								
sp., young								
Fasciolaria sp.								
apicina Dall				×	×		×	
gigantea Kiener		×					×	×
Busycon maximum (Conrad)			×				×	
perversum (Linné)	×	×	×	×	×		×	
carica (Gmelin)		×		×				
canaliculatum (Linné)	?	×		×			×	
pyrum (Dillwyn)		×		×			×	×
Fusinus caloosaensis (Heilprin)				×			×	×
Ilyanassa isogramma Dall			?	×				
obsoleta var. *irrorata* Conrad				×				
Nassarius vibex (Say)		×		×			×	×
near *consensa* (Ravenel)								
Anachis avara amydra Dall?							×	×
obesa C. B. Adams, var.				×			?	?
Astyris lunata Say		×					×	×
Aesopus stearnsii (Tryon)		×					×	
Murex pomum Gmelin	×	×		×			×	
Eupleura caudata (Say)		×		×			×	
caudata var. *sulcidenta* Dall		×		×				
Epitonium lineatum (Say)		×			×		×	
krebsii (Mörch)		×			×			
sp.								
Melanella concoidea (Kurtz and Stimpson)		×					×	
Odostomia (*Chrysallida*) sp.								
Turbonilla (*Pyrgiscus*) sp.								
Turritella sp.								
Crucibulum auricula (Gmelin)	×	×		×			×	×
Crepidula fornicata (Linné)	×	×	×	×	×		×	×
convexa Say		×	?	×	×		×	×
aculeata Gmelin?				×			×	×
plana Say	×	×		×	×		×	×
ponderosa H. C. Lea				×			×	×
Natica? sp.								
Polinices duplicatus (Say)	×	×		×	×		×	×
Sinum perspectivum (Say)		×		×	×			
Turbo crenulatus Gmelin		×		×		×	×	×

apparently an undescribed species.

Of the Pelecypoda, the family Arcidae is represented by two genera and an abundance of individuals. *Arca alcima* Dall and *Eontia variabilis* MacNeil are very plentiful. *Ostrea sculpturata* Conrad and *O. virginica* Gmelin are both common. *Pecten eboreus* var. *solaroides* Heilprin is much more plentiful than in most Pliocene exposures in north Florida. *Mulinia lateralis* Say shows the largest number of individuals of any of the Pelecypoda. *M. contracta* (Conrad) is less common and *M. congesta* (Conrad), light form, is represented by only 15 valves. The genus *Dosinia* is represented by two species, but only *D. discus* Reeve is common. Individuals of *Chione cancellata* (Linné) are abundant. *Venus rileyi* Conrad is represented by a number of specimens. Individuals of *Phacoides anodonta* (Say), *P. mutilineatus* (Tuomey and Holmes), and *P. waccamawensis* Dall are numerous.

Forty-seven identifiable species and varieties of Pelecypoda and 40 species and varieties of Gasteropoda are listed from Sanford. Of the Pelecypoda, 22 are known from the Miocene Choctawhatchee formation, and 25 live today in either the Atlantic or the Gulf of Mexico. The Gasteropoda show a much closer affinity to the Recent fauna; only 11 of the species are known from the Choctawhatchee, but 31 species are still living.

Of the species listed, only one is particularly common in the Miocene. This is *Mulinia congesta* (Conrad). The specimens present in this fauna are less robust than the typical Miocene specimens. This lighter form is common in the Pliocene.

All of the species listed are known from the Pliocene, and only one, *Eontia variabilis quadrata* MacNeil, a Waccamaw species in North Carolina, has not previously been reported from the Pliocene Caloosahatchee marl of Florida. The fauna seems closely allied to that from the exposure one-half mile south of DeLeon Springs in Volusia County. Sixty-six species, or approximately 76 per cent of the species listed here, are known to occur there. Sixty-nine of the species occur in the Pliocene from the Caloosahatchee River; 48 are known from Shell Creek; 36 occur at Deland; 19 were reported at Nashua; 14 occur in collections from the vicinity of Orange City.

The number of species listed as present in the typical Caloosahatchee fauna is numerically greater than that from DeLeon Springs; but there is a complete absence of many of the genera represented abundantly on the Caloosahatchee River. Species of *Turritella* that are quite diagnostic of the faunas on Shell Creek and Caloosahatchee River are absent from this collection and collections from DeLeon Springs. Therefore it is evident that the fauna at Sanford is very similar to if not identical with that of the exposure one-half mile south of DeLeon Springs. These beds were called Nashua marl by Matson and Clapp (1909) but Cooke and Mossom (1929) regarded the Nashua as merely a slightly different facies of the Caloosahatchee marl not worthy of a distinctive name.

A comparison with the recent fauna has produced significant data. Fifty-six of the species are reported to be living today. Of these, 24 are known from North Carolina southward. Twenty-five range both north and south of North Carolina. Only four are now believed to be confined to the fauna of Florida and the West Indies. These are *Cancellaria tenera* Philippi, *Epitonium krebsii* (Mörch), *Crucibulum auricula* (Gmelin), and *Eupleura caudata* var. *sulcidenta* Dall. One, *Cancellaria conradiana* Dall, is now known only from deep water in the Gulf of Mexico. *Nucula proxima* var. *trunculus* Dall is now known only between Nova Scotia and New York. One species, *Marginella limatula* Conrad, occurs at depths of 25 to 100 fathoms off the North Carolina coast. *Marginella bella* Conrad has not been reported north of Hatteras or south of Cape Fear. *Mytilus exustus* Linné, *Chione cancellata* (Linné), *Phacoides trisulcatus* Conrad, and *Divaricella quadrisulcata* d'Orbigny range as far southward as Brazil. Fifteen of the species are known from the Gulf along the Texas coast. Of these, *Nucula proxima* Say, *Ostrea virginica* Gmelin, *Mulinia lateralis* Say, *Crepidula convexa* Say, *C. plana* Say and *C. fornicata* Linné are known as far north in the Atlantic as the southern Canadian coast; *Tagelus divisus* Spengler and *Abra aequalis* Say are known from the

New England coast; *Terebra dislocata* Say has been recorded northward to Maryland; and *Mytilus exustus* Linné, *Terebra protexta* Conrad, *Oliva sayana* Ravenel, *Busycon perversum* (Linné) and *B. pyrum* (Dillwyn) are known to North Carolina. One species, *Dosinia discus* Reeve, extends from New Jersey to Vera Cruz.

It is evident from a study of the distribution that more than 85 per cent of the living species in the list have a very wide geographic range. Twenty-two of the total of 56 species are known from both the colder waters of the northeast coast of the United States and from the warmer waters of Florida and the Gulf of Mexico. Nearly all of these species are capable of adaptation to extremely variable ecologic conditions.

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CORRECTIONS TO THE BASAL BONNETERRE FAUNA

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SEVERAL corrections to my recent paper on the "Fauna of the Basal Bonneterre dolomite (Upper Cambrian) of southeastern Missouri" (Journal of Paleontology, vol. 14, January 1940) are here reported:

Because of priority of publication, *Holcacephalus* (genotype *H. granulatus* Resser = *Norwoodia tenera* Walcott) has precedence over the name *Norwoodina* proposed (p. 48) for a genus of the Norwoodidae. Although the syntypes, U.S.N.M. 94844, of *H. granulatus* Resser, are very incomplete, a full knowledge of the characters of the genus is furnished by the specimens of *Holcacephalus tenera* Walcott) U.S.N.M. 61615–61621, from two miles south of Marjum Pass, House Range, Utah.

Some of the sketches of agnostid cephala and pygidia which were presented to show the course of the dorsal furrows, do not agree in proportions with the photographs of the specimens. The drawings of all the cephala and the pygidium of *Kormagnostus esterius* Lochman are in correct proportions, but in the drawings of the pygidia of *Kormagnostus splendens* Lochman, "*Agnostus*" *nordicus* Lochman, *Kormagnostus senatus* Lochman, and *Pseudagnostus mesleri* (Resser) the axial lobe should have been shown as twice the width of the pleural lobes.

The word *Spissicephalus* in the table on page 12 should read *Syspacheilus*.

JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 5, PP. 516–518, 1 TEXT FIG., SEPTEMBER, 1940

ALSATASPIS BAKERI, A NEW LOWER ORDOVICIAN TRILOBITE

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ABSTRACT—A new genus and species of trilobite, *Alsataspis bakeri*, belonging to a new family, is described from the Marathon series of Trans-Pecos Texas.

DURING the summer of 1936 C. L. Baker made collections of fossils from the Paleozoic sections exposed in the vicinity of Marathon, Brewster County, Texas. While collecting in the beds of the Marathon series below the Alsate shales, Baker broke out of the limestone an unusually well preserved trilobite of exotic appearance. It is associated with a fauna consisting of *Tetragraptus*, numerous dendroid graptolites, *Hyolithes*, and *Lingula*. The strata from which the fossil was collected are equivalent in age to some part of the Beekmantown Ordovician of New York State[1] The specimen is described below as a new genus and new species.

Family ALSATASPIDAE Turner, n. fam.

The family Alsataspidae is based on the new genus *Alsataspis*. It is apparently related to the Raphiophoridae and Dionididae. It differs from the Raphiophoridae by the large number of thoracic segments and the separation of the base of the anterior spine from the glabella. It resembles the Dionididae in the trace of the facial sutures and the suggestion of longitudinal notches on the glabella. It differs in having a prominent anterior spine and in lacking the prominently pitted brim on the cephalon.

Genus ALSATASPIS Turner, n. gen.

Genotype, *Alsataspis bakeri* Turner, n.sp.

Generic characterization: Cephalon broad, provided with a long anterior spine and genal spines projecting widely and sweeping backward. Eyes apparently lacking. Thorax long, uniformly tapering with many segments, broadest three or four segments posterior to the cephalon. Axial lobe uniformly tapering from anterior to posterior end. Pleural lobes broad anteriorly, narrow posteriorly. Pygidium small, not well defined.

ALSATASPIS BAKERI Turner, n. sp.
Figure 1

Cephalon smooth, broad, the sutures cutting the posterior edge of the cephalon near the distal margin of the pleural lobes, from this point curving gently outward to a point opposite the central line of the genal spines, from which point it turns inward and continues forward to an anterior lateral shoulder of the cephalon. Genal spines incomplete, located on free cheeks, tapering rapidly outward to a point in advance of the posterior margin of the cephalon. From this point they sweep backward behind the middle of the thorax and outward a distance equal to the width of the thorax. Distal end of spine flattened, partly lost, midsection round or oval. Anterior spine an extension of the general surface, not of the glabella, rounded in distal, apparently flattened in proximal section; rapidly tapering forward near base, becoming more gently tapering anteriorly; distal end curving upward. Anterior lateral margins of cephalon curve concavely forward from the genal spines to a point opposite the base of the anterior spine, where they turn sharply inward to the spine. Cephalon with a slightly swollen half-oval area at the base of the spine, which disappears close to the anterior edge of the glabella. Glabella somewhat crushed, divided into two lateral lobes, which may be quite accidental. No transverse glabella furrows identifiable. There is a slight suggestion of two longitudinal grooves at the rear of the glabella, as in *Dionide*. No traces of eyes or associated structures determinable. The occipital furrows reach the posterior margin behind the glabella, there being no nuchal ring, and

[1] KING, P. B., *1937*, The geology of the Marathon region, Texas: *U. S. Geol. Survey, Prof. Paper* 137, p. 30.

diverge forward from the posterior of the cephalon as they extend outward across the fixed cheeks. Thorax and pygidium with 43 segments, of which 12 may belong to the pygidium, greatest width three or four segments behind the cephalon; from that point pygidium is not readily distinguishable from the thorax. Under the microscope the segments all appear to be articulated. The final segment is a small quarter-lunar brim. About 12 axial and 10 pleural segments from the posterior end, a change in the ap-

FIG. 1.—*Alsataspis bakeri* Turner. Holotype, ×1.

tapering fairly uniformly to the posterior end; axial lobe slender, tapering uniformly to posterior end; pleural lobes bending sharply along the margins at the anterior part of the thorax, gradually breaking more gently toward the posterior part of thorax. Anterior pleural segments of the thorax traversed by deep, slightly diagonal furrows, so that the ribs are made up of the posterior part of one segment and the anterior part of the adjacent segment. This feature dies out near the twentieth segment as the furrows become shorter and shorter. Posteriorly from the point on the thorax, where the furrows become short, the pleural segments are finely striated diagonally across the ribs, the ends of the striae bending strongly forward near the ends of the furrows. The pearance and a slight dislocation on the left side suggest that the pygidium may actually begin at that point. Extensive search revealed no trace of appendages on the ventral side.

Observations.—In the development of spines, the presence of the genal spines on the free cheeks, the course of the facial sutures, and the lack of eyes, a possible relationship to *Ampyx* (*Lonchodomus*) is suggested. Marked differences are the large number of thoracic segments, the small pygidium, the apparent division of the glabella into two lateral lobes, and the separation of the inflated base of the anterior spine from the glabella. In the shape of thorax and the large number of segments it resembles *Acrocephalites* from the Cam-

brian. A relationship to *Dionide* is suggested by the trace of the facial sutures, by the glabella contracting posteriorly, the faint suggestion of longitudinal notches at the rear of the glabella, and the deep furrows which lie on the pleural segments.

Dimensions.—Total length 94 mm., length of thorax 43.5 mm., maximum width of thorax 32.8 mm., maximum width of axial lobe 7.4 mm., width of glabella approximately 14 mm., length of anterior spine approximately 31.5 mm.

Type data.—Holotype in Geology Department, Agricultural and Mechanical College of Texas, College Station, Texas.

Type locality.—Upper part of Marathon series underlying the Alsate shale at its type locality on Alsate Creek, 6.2 miles S. 55° W. of railroad crossing at Marathon, lying northwest of the bend in the road leading to Roberts Ranch, Marathon quadrangle, Brewster County, Texas.

Acknowledgments.—I am deeply indebted to Dr. Percy E. Raymond of the Museum of Comparative Zoology, Harvard University, for his kindly criticism of the manuscript and suggestions regarding the structure and affinities of this new species.

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JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 5, P. 518, SEPTEMBER, 1940

CANTHARUS BENTSONAE NEW NAME FOR CANTHARUS COWLITZENSIS TURNER

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As a paper by Dr. B. L. Clark was in press at the same time as one of my own, the duplication of the specific name *Cantharus cowlitzensis* was not detected. This has been called to my attention by Miss Herdis Bentson of the Museum of Paleontology at the University of California. Since *Cantharus* (*Eocantharus*) *cowlitzensis* Clark[1] appeared first, I propose the name *Cantharus bentsonae* to replace *Cantharus cowlitzensis* Turner.[2]

[1] CLARK, B. L., *May 1938, Geol. Soc. America, Bull.*, vol. 49, p. 714, pl. 4, figs. 7–10.
[2] TURNER, F. E., *June 1938, Geol. Soc. America, Special Paper* 10, p. 79, pl. 16, fig. 22.

JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 5, PP. 519–520, 6 TEXT FIGS., SEPTEMBER, 1940

A PLEISTOCENE OCCURRENCE OF LIBINIA DUBIA, A BRACHYURAN

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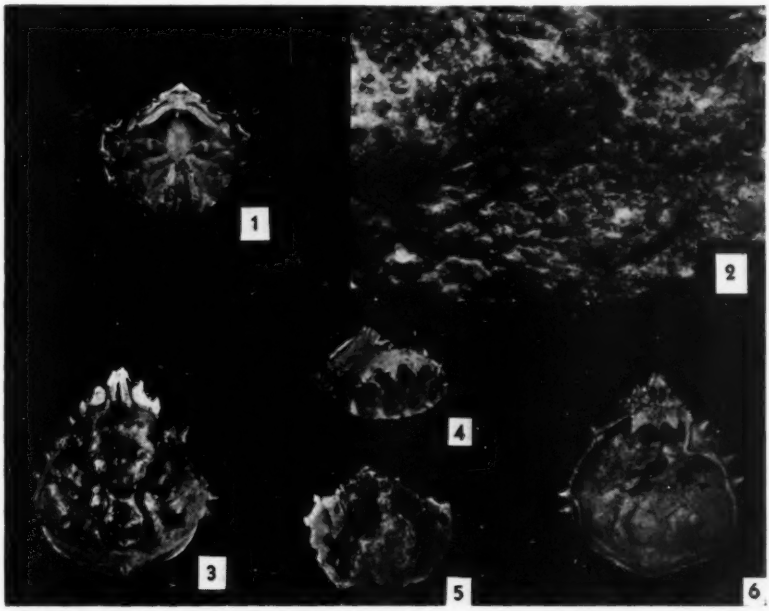
IN THE summer of 1938 an unusual specimen of the spider crab, *Libinia dubia* Milne Edwards, was collected from the Pamlico formation (late Pleistocene) at Wailes Bluff on the Potomac River near Point Lookout, Maryland. The fossil was removed from a layer one foot below the top of the so-called "bed below the oyster bed."

The specimen consists of the cephalothorax and the sternum, the abdomen and appendages (except a few fragments of the pleopods or swimmerets adhering to the sternum) not being found. The individual was a female crab measuring 28.0 mm. in length and 24.5 mm. in width, including spines, so the animal at death was probably about one-third grown. By reason of subsequent accidental breaking of the cephalothorax, the inner part of the animal was revealed. As the thoracic walls are almost complete, details of the partially calcified chitinous interior skeleton can be studied. Moreover, within, and occupying about half of the thoracic cavity, is a brown nodosely tubular structure, which, when carefully examined, appears to be no encrusting organism, but part of the viscera of the spider crab itself. Because of its size, its manner of filling the thoracic cavity, its



FIGS. 1–6.—*Libinia dubia* Milne Edwards. *1*, Ventral view of sternum, ×1; *2*, surface of digestive gland shown at right center of *5*; ×10; *3*, dorsal view of carapace, ×1; *4*, left side of sternum with thoracic wall above the five openings for leg muscles, ×1; *5*, dorsal view of sternum, looking in the thoracic cavity, ×1; *6*, ventral view of interior of carapace with digestive gland adhering to the carapace ×1.

vesicular structure, its color, and its caecalike appearance, it is concluded that this chitinous material was within the hepatopancreas of the crab. Thus, although the remains of *Callinectes* so commonly found in the same deposit are fragmental and poorly preserved, this representative of *Libinia*, apparently by reason of better calcification of its chitinoid skeleton, is so remarkably well preserved as to retain part of its digestive gland.

The openings in the thorax for the muscles of the five large appendages are well shown, as are also at least three other much smaller openings for the muscles of the mouth appendages. These three openings successively decrease in size anteriorly as the size of the muscles decreases. Likewise, the area of cross section of the gill chamber (used as an index of volume) is restricted anteriorly, resulting in the presence of either smaller or fewer gills associated with the appendages of the mouth. From this decided reduction in gill size it might be postulated that *Libinia dubia* is evolving toward the decapod crustaceans with five pairs of gills, and that most of the transition had already been achieved by the Pleistocene epoch.

Modern representatives of *L. dubia* are distributed along the Atlantic coast from Cape Cod, Massachusetts to Corpus Christi, Texas, and also along Cuban and West African strands. This crab is found on mud flats, oyster bars, and as deep as 25 fathoms in varying bottom habitats. *Libinia dubia* is one of nine modern species of the genus but is not the most common spider crab today. As a fossil, it has been reported previously only in the form of isolated claws. One right finger is known from the Yorktown formation (upper Miocene) of Virginia and eight fingers were recovered from the Cape May formation of New Jersey (Rathbun, 1925, 1935). The latter deposit is approximately the same age as the Pamlico formation.

The author wishes to thank Miss Phoebe Jane Beall, who discovered this specimen (Walker Museum no. 45193) and presented it to him for study.

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